FINAL REPORT

Wabamun and Area Community Exposure and Health Effects Assessment Program

August 2006

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The Wabamun and Area Community Exposure and Health Effects Assessment

Final Report

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The Wabamun and Area Community Exposure and Health Effects Assessment Program is the fourth in a series of reports published by the Health Surveillance Branch at Alberta Health and Wellness.

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The Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Technical Report, 2000.
The Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Methods Report, 2000.
The Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Pilot Study Report, 1997.

Disclaimer: The organizations represented on the Steering Committee are recognized for their contributions and support of the Wabamun and Area Community Exposure and Health Effects Assessment Program. Although the program is directed by a multi-stakeholder consultation process, this scientific report may not reflect the views of these organizations. Any inquiries regarding the methods utilized in compiling and analyzing information and samples collected from the participants should be directed towards the Public Health Surveillance and Environmental Health Branch, Alberta Health and Wellness.

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This report provides the results of a community exposure and health effects assessment conducted in Wabamun and surrounding area during the summer and fall of 2004. The assessment used a protocol developed in Alberta to assess personal exposure and the potential health impact of airborne contaminants.

The list of members below reflects the names of the organizational representatives at the time of printing of this report. It should be acknowledged that representatives for some of these organizations have changed over time and that the contributions of these individuals were valued and appreciated.

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Table of Contents

1.0 Executive Summary 11
- 1.1 Objectives 11
- 1.2 Methods and Analysis 11
- 1.3 Significant Findings 11
- 1.4 Recommendations 14

2.0 Introduction 15

3.0 Background and Rationale 16

4.0 Program Objectives 17

5.0 Program Method and Protocol 18
- 5.1 Recruitment and Sample Selection 18
- 5.2 Study Design 19
- 5.3 Program Logistics 22
- 5.4 Exposure Monitoring Procedures 24
- 5.5 Neurocognitive Functioning 26
- 5.6 Questionnaires 26
- 5.7 Biological Tests 27
- 5.8 Health Records Analysis 27

6.0 Characteristics of the Sample 28
- 6.1 Sample Size 30
- 6.2 Age and Gender 31
- 6.3 Marital Status 32
- 6.4 Education 33
- 6.5 Language 33
- 6.6 Occupation 34
- 6.7 Income 34
- 6.8 Smoking 35
- 6.9 Body Mass Index 35
- 6.10 Nutritional Intake 36
- 6.11 Local Wild Food Sources 37
- 6.12 Sources of Drinking Water 37
- 6.13 Physical Activity Level 37
- 6.14 Length of Residence 38
- 6.15 Meteorological Data 39
- 6.16 Time Activity Diaries 40

7.0 Air-Borne Contaminants 42
- 7.1 Passive Samplers 42
- 7.2 Particulate Samplers 82
- 7.3 Polycyclic Aromatic Hydrocarbons (PAHs) 86

8.0 Exposure Relationships 87
- 8.1 A General Model of Potential Relationships 87
- 8.2 Methods of Analysis 90
- 8.3 Presentation of Results 90

8.4 Nitrogen Dioxide (NO_2) 92
8.5 Sulfur Dioxide (SO_2) 95
8.6 Ozone (O_3) 98
8.7 Volatile Organic Compounds 101
8.8 Particulate Analysis: $PM_{2.5}$ 128

9.0 Biomarkers of Exposure 133
9.1 Nicotine 133
9.2 Mercury 134
9.3 Arsenic 135
9.4 Benzene 136
9.5 Toluene 136
9.6 Ethylbenzene 137
9.7 Xylene 137
9.8 Summary 138

10.0 Biomarkers of Effect 139
10.1 Immunoglobulin gamma E (IgE) 139
10.2 Autoantibodies 142
10.3 Lung Function 145
10.4 Neurocognitive Functioning 147

11.0 Measures of Health 159
11.1 Occupational Health Questionnaire 159
11.2 General Health Questionnaire (GHQ) 160
11.3 Previous Diagnoses 160

12.0 Analysis of Health Records 162
12.1 Morbidity of Respiratory Disorders 164
12.2 Mortality of Selected Causes of Death 168
12.3 Comparison of Overall Illness: Participants vs. the General Population 172
12.4 Summary of Analysis of Health Records 172

13.0 Exposure Sources 173
13.1 Sulfur Dioxide (SO_2) 174
13.2 Nitrogen Dioxide (NO_2) 176
13.3 Ozone 179
13.4 $PM_{2.5}$ 180

14.0 Conclusions 181
14.1 The Program Sample 181
14.2 Measures of Exposure 181
14.3 Measures of Health 183

15.0 Abbreviations 185

16.0 Definitions 186

17.0 Endnotes 191

Appendix A: Biomarkers of Exposure for Children
Appendix B: Supplementary - Immunoglobulin Gamma E
Appendix C: Supplementary - Health Record Analysis
Appendix D: Multiple Sclerosis in Wabamun and Surrounding Area

List of Figures

Figure 1: Continuum of Exposure 16
Figure 2: Participants Recruited by Week throughout Program Period 18
Figure 3: Overview of Wabamun Program Area 28
Figure 4: Distribution of Devon Participants 29
Figure 5: Distribution of Spruce Grove Participants 29
Figure 6: Distribution of Stony Plain Participants 30
Figure 7: Age and Gender Distribution – Urban/Rural Participants 31
Figure 8: Age and Gender Distribution – Paul First Nation Participants 32
Figure 9: Marital Status 32
Figure 10: Education Level 33
Figure 11: Distribution by Occupation in Samples 34
Figure 12: Distribution of Household Income 35
Figure 13: Distribution of Body Mass Index 36
Figure 14: Wind Rose Diagram Showing Wind Characteristics at the Wagner Air Monitoring Station 39
Figure 15: Wind Rose Diagram Showing Wind Characteristics at the Meadows Air Monitoring Station 39
Figure 16: Wind Rose Diagram Showing Wind Characteristics at the Genesee Air Monitoring Station 40
Figure 17: Average Proportion of Time Spent in a Day by Participants 41
Figure 18: Distribution of Nitrogen Dioxide 45
Figure 19: Temporal Trend in Nitrogen Dioxide Concentration 46
Figure 20: Relationship between Exposures to Nitrogen Dioxide by Sampler Site 47
Figure 21: Distribution of Sulfur Dioxide 48
Figure 22: Temporal Trend in Sulfur Dioxide Concentration 49
Figure 23: Relationship between Exposures to Sulfur Dioxide by Sampler Site 50
Figure 24: Distribution of Ozone 51
Figure 25: Temporal Trend in Ozone Concentration 53
Figure 26: Relationship between Exposures to Ozone by Sampler Site 53
Figure 27: Distribution of Hexane 54
Figure 28: Temporal Trend in Hexane Concentration 55
Figure 29: Relationship between Exposures to Hexane by Sampler Site 55
Figure 30: Distribution of 3-Methylhexane 56
Figure 31: Temporal Trend in 3-Methylhexane Concentration 57
Figure 32: Relationship between Exposures to 3-Methylhexane by Sampler Site 57
Figure 33: Distribution of Benzene 58
Figure 34: Temporal Trend in Benzene Concentration 59
Figure 35: Relationship between Exposures to Benzene by Sampler Site 60
Figure 36: Distribution of Heptane 61
Figure 37: Temporal Trend in Heptane Concentration 62
Figure 38: Relationship between Exposures to Heptane by Sampler Site 62
Figure 39: Distribution of Toluene 63
Figure 40: Temporal Trend in Toluene Concentration 64
Figure 41: Relationship between Exposures to Toluene by Sampler Site 64
Figure 42: Distribution of Octane 65
Figure 43: Temporal Trend in Octane Concentration 66
Figure 44: Relationship between Exposures to Octane by Sampler Site 66
Figure 45: Distribution of Ethylbenzene 67
Figure 46: Temporal Trend in Ethylbenzene Concentration 68
Figure 47: Relationship between Exposures to Ethylbenzene by Sampler Site 68
Figure 48: Distribution of *m*-, *p*- Xylene 69

Figure 49: Temporal Trend in *m*-, *p*-xylene Concentration 70
Figure 50: Relationship between Exposures to *m*-, *p* - Xylene by Sampler Site 70
Figure 51: Distribution of *o*-Xylene 71
Figure 52: Temporal Trend in *o*-Xylene Concentration 72
Figure 53: Relationship between Exposures to *o*-Xylene by Sampler Site 72
Figure 54: Distribution of Nonane 73
Figure 55: Temporal Trend in Nonane Concentration 74
Figure 56: Distribution of Decane 75
Figure 57: Temporal Trend in Decane Concentration 76
Figure 58: Relationship between Exposures to Decane by Sampler Site 76
Figure 59: Distribution of Limonene 77
Figure 60: Temporal Trend in Limonene Concentration 78
Figure 61: Relationship between Exposures to Limonene by Sampler Site 78
Figure 62: Distribution of *N*-propylbenzene 79
Figure 63: Temporal Trend in *N*-propylbenzene Concentration 80
Figure 64: Relationship between Exposure to *N*-propylbenzene by Sampler Site 80
Figure 65: Distribution of *N*-butylbenzene 81
Figure 66: Distribution of $PM_{2.5}$ 83
Figure 67: Relationship between Exposures to $PM_{2.5}$ by Sampler Site 84
Figure 68: Overall Concentration of Metals in Particulate 85
Figure 69: Concentration of Metals in $PM_{2.5}$ 85
Figure 70: A General Ordering of Factors Influencing Personal Exposure 89
Figure 71: General Model of Personal Exposure Used to Investigate Direct and Indirect Effects 90
Figure 72: Results of Model of Personal Exposure to Nitrogen Dioxide 94
Figure 73: Results of Model of Personal Exposure to Sulfur Dioxide 97
Figure 74: Results of Model of Personal Exposure to Ozone 100
Figure 75: Results of Model of Personal Exposure to Benzene 103
Figure 76: Results of Model of Personal Exposure to Toluene 105
Figure 77: Results of Model of Personal Exposure to Ethylbenzene 107
Figure 78: Results of Model of Personal Exposure to *o*-Xylene 109
Figure 79: Results of Model of Personal Exposure to *m*-, *p* - Xylene 111
Figure 80: Results of Model of Personal Exposure to Limonene 113
Figure 81: Results of Model of Personal Exposure to Hexane 115
Figure 82: Results of Model of Personal Exposure to *3*-Methylhexane 117
Figure 83: Results of Model of Personal Exposure to Heptane 119
Figure 84: Results of Model of Personal Exposure to Octane 121
Figure 85: Results of Model of Personal Exposure to Nonane 123
Figure 86: Results of Model of Personal Exposure to Decane 125
Figure 87: Results of Model of Personal Exposure to *N*-propylbenzene 127
Figure 88: Results of Model of Personal Exposure to $PM_{2.5}$ Showing Direct and Indirect Effects of Factors 130
Figure 89: Biplot Representation of Semi-Partial R for Determinant Sets of Chemicals (Personal Concentrations) 132
Figure 90: NES2 Finger Tapping Test (with 95% Confidence Intervals) 149
Figure 91: NES2 Associate Learning Test (with 95% Confidence Intervals) 149
Figure 92: NES2 Switching Attention Test (with 95% Confidence Intervals) 150
Figure 93: NES2 Mood Scales (with 95% Confidence Intervals) 150
Figure 94: NES2 Continuous Performance Test (with 95% Confidence Intervals 151
Figure 95: NES2 Simple Reaction Time Test (with 95% Confidence Intervals) 151

Figure 96: NES2 Symbol-Digit Test (with 95% Confidence Intervals) 152
Figure 97: NES2 Pattern Comparison Test (with 95% Confidence Intervals) 152
Figure 98: NES2 Pattern Memory Test (with 95% Confidence Intervals) 153
Figure 99: NES2 Serial Digit Learning Test (with 95% Confidence Intervals) 153
Figure 100: NES2 Colour-Word Test (with 95% Confidence Intervals) 154
Figure 101: NES2 Vocabulary Test (with 95% Confidence Intervals) 154
Figure 102: NES2 Delayed Associate Recognition Test (with 95% Confidence Intervals) 155
Figure 103: Estimated Relative Risk for Prevalence of Selected Respiratory Disorders: WACEHEAP Compared to CEHEAP Comparative Communities, 1995-2004 167
Figure 104: Age- Standardized Mortality Rate of All Causes of Death, WACEHEAP, 1984 – 2004 169
Figure 105: Comparison of Age Standardized Mortality Rates of Selected Causes of Death Between the WACEHEAP and Comparative CEHEAP Communities, 1984-2001 (with 95% Confidence Interval) 170
Figure 106: Average SO$_2$ Levels at the Genesee Air Monitoring Station (January 2004 to December 2004) plotted by Wind Speed and Wind Direction 175
Figure 107: Average SO$_2$ Levels at the Wagner Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction 175
Figure 108: Average SO$_2$ Levels at Meadows Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction 176
Figure 109: Average NO$_2$ Levels at Genesee Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction 177
Figure 110: Average NO$_2$ Levels at Wagner Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction 177
Figure 111: Average NO$_2$ Levels at Meadows Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction 178
Figure 112: Average O$_3$ Levels at Genesee Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction 179
Figure 113: Average PM$_{2.5}$ Levels at Genesee Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction 180

List of Tables

Table 1: Components of the Program 21
Table 2: Summary of Passive Sampler Detection Limits 25
Table 3: Number of Participants Completing Each Program Component 31
Table 4: Summary of Nutritional Intake 36
Table 5: Distribution of Length of Residency 38
Table 6: Activity Mix by Gender and Job Status 40
Table 7: Samplers and Chemical Concentrations Measured 42
Table 8: Distribution of Passive Air Monitors 43
Table 9: Comparison of NO$_2$ Levels in $\mu g/m^3$ with Guidelines and Other Studies 46
Table 10: Comparison of SO$_2$ Levels in $\mu g/m^3$ with Guidelines and Other Studies 49
Table 11: Comparison of O$_3$ Levels in $\mu g/m^3$ with Guidelines and Other Studies 52
Table 12: Comparison of Benzene Levels in $\mu g/m^3$ with Guidelines and Other Studies 59
Table 13: Metals Analyzed from Particulate Samples 82
Table 14: Distribution of Particulate Matter (PM$_{2.5}$) Filters 83
Table 15: Comparison of PM$_{2.5}$ Levels ($\mu g/m^3$) with Guidelines and Other Studies 84
Table 16: Comparative Multiple Regression Coefficients for Variable Sets 92
Table 17: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 93
Table 18: Comparative Multiple Regression Coefficients for Variable Sets 95

Table 19: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 96
Table 20: Comparative Multiple Regression Coefficients for Variable Sets 98
Table 21: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 99
Table 22: Comparative Multiple Regression Coefficients for Variable Sets 102
Table 23: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 102
Table 24: Comparative Multiple Regression Coefficients for Variable Sets 104
Table 25: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 104
Table 26: Comparative Multiple Regression Coefficients for Variable Sets 106
Table 27: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 106
Table 28: Comparative Multiple Regression Coefficients for Variable Sets 108
Table 29: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 108
Table 30: Comparative Multiple Regression Coefficients for Variable Sets 110
Table 31: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 110
Table 32: Comparative Multiple Regression Coefficients for Variable Sets 112
Table 33: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 112
Table 34: Comparative Multiple Regression Coefficients for Variable Sets 114
Table 35: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 114
Table 36: Comparative Multiple Regression Coefficients for Variable Sets 116
Table 37: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 116
Table 38: Comparative Multiple Regression Coefficients for Variable Sets 118
Table 39: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 118
Table 40: Comparative Multiple Regression Coefficients for Variable Sets 120
Table 41: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 120
Table 42: Comparative Multiple Regression Coefficients for Variable Sets 122
Table 43: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 122
Table 44: Comparative Multiple Regression Coefficients for Variable Sets 124
Table 45: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 124
Table 46: Comparative Multiple Regression Coefficients for Variable Sets 126
Table 47: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 126
Table 48: Comparative Multiple Regression Coefficients for Variable Sets 128
Table 49: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations 129
Table 50: Self-Reported Smoker Status and Detection of Nicotine 133
Table 51: Mean of Urinary Arsenic Species (µg/L) in Different Studies 135
Table 52: Means and Ranges of Measured Biomarkers of Exposure in Adults 138
Table 53: Total Serum IgE Results 140
Table 54: Distribution of Total Serum IgE 140
Table 55: Ingestant Screen Results 140
Table 56: Inhalant Screen Results 141
Table 57: Autoantibody Specificities 143
Table 58: Summary of Spirometry Data 145
Table 59: Differences in the Prevalence of Reported Respiratory Symptoms between Wabamun, Fort Saskatchewan, Fort McMurray and Lethbridge 146
Table 60: Comparison between Study Sample and Other Study Populations 147
Table 61: Frequency of Experiencing Symptoms (NES2) 156
Table 62: Symptom Composite Scales (NES2) 157
Table 63: Verbal Digit Span Results 158
Table 64: Frequency of Experiencing Self – Reported Symptoms 159
Table 65: GHQ Score - Percentage of Respondents by Gender 160
Table 66: Percentage with Self-Reported Previously Diagnosed Condition 161

Table 67: Demographic and Socio-economic Characteristics of Community Populations, 1995-2004 ... 163
Table 68: 10-Year Period Prevalence of Selected Respiratory Disorders by Age Group among Permanent Residents: Wabamun area vs. Other CEHEAP Communities, 1995 – 2004 ... 165
Table 69: 10–Year Period Prevalence of Respiratory Disorders by First Nations Status among Permanent Residents Wabamun area vs. Other CEHEAP Communities, 1995 – 2004 ... 166
Table 70: Mean and Median Number of Visits for Selected Respiratory Disorders by Community, the 1995 Population Cohort during a 10-Year Observation ... 168
Table 71: Proportion Visiting a Health Care Provider and Average Number of Visits for Any Illness by Age Group, Wabamun and Area, January to December 2004 ... 172
Table 72: Summary of Outdoor Exposure Source Apportionment ... 174

1.0 Executive Summary

1.1 Objectives

This report summarizes the results of a community exposure and health effects assessment undertaken in the Wabamun area to gauge the impact of airborne contaminants on the health of the population. The report describes the population and personal distribution of exposure to airborne chemicals and particulates in the Wabamun area. Using a personal exposure model, the relative contribution of various exposure sources and pathways to airborne chemicals is estimated and associations between exposure to airborne chemicals and human health effects are described.

1.2 Methods and Analysis

The data used for the analysis was collected over a 21-week period (May 17, 2004 to October 22, 2004), using volunteers from the cities of Stony Plain, and Spruce Grove and towns of Devon, Wabamun and Thorsby and surrounding rural areas. Members of the Paul First Nation were also recruited for this program. Data was evaluated and, where applicable, additional comparisons were made to the scientific literature or to comparable data collected elsewhere in Alberta. The program collected a variety of measures for each participant, including personal, indoor, and outdoor levels of selected contaminants (sulfur dioxide, nitrogen dioxide, ozone, a group of volatile organic compounds, and particulate matter), measures of other sources of exposure, diet and health behaviours, and selected health outcomes.

1.3 Significant Findings

Despite ongoing recruitment activities, the project co-ordinator was unable to obtain the targeted 300 volunteers. In total 196 individuals volunteered of which 151 provide a complete set of measures for inclusion into the required analysis. This suggests that exposure to contaminants from air-borne sources may not be an issue of primary concern to most residents of the Wabamun area. It seems inconsistent with expectations in view of the notoriety given to concerns with air quality in the region.

The sample, although slightly smaller than anticipated, provided measures of exposure from all areas surrounding the community of Wabamun and surrounding region. Two subgroups were created, urban/rural with 101 participants and 51 members of the Paul First Nation. The sample generally represented the rest of the population in gender and level of education, but had a larger proportion of females and individuals over 40 years of age. A significantly higher proportion of the Paul First Nation participants were smokers (64.5%) versus the urban/rural sample with only 10.9%. Based on self-reported residential histories, 49.5% of urban/rural participants have resided in the program area for less than 10 years. Participants from the Paul First Nation indicated longer residency periods with 63% indicating they have lived in the area for 15 years or more.

Analysis of the individual measures of exposure indicated:

- Ambient concentrations were not a good predictor of personal exposures. Indoor levels of a contaminant either at home or work are the major influences of personal exposure to the assessed airborne contaminants.
- Ambient levels of nitrogen dioxide (NO_2) levels were low compared to existing guidelines and were comparable to levels found in similar studies. The most important exposure source of nitrogen dioxide (NO_2) was identified as local sources. Influences from background and regional sources were estimated at 32% and 12% respectively.

- Levels of sulfur dioxide measured in Wabamun were very low compared to existing guidelines. The exposure source to sulfur dioxide (SO_2) was contributed to equally between local, regional and background sources.
- Personal and indoor levels of ozone were very low. As the outdoor levels were an order of magnitude higher, this suggests that ambient measures are an inadequate measure of personal exposure. Indoor, local, and regional influences that increase exposure were not identified.
- Indoor concentrations were the predominant factor affecting personal exposure to volatile organic compounds (VOCs). Other factors were of only minor relative importance, which suggests that exposure to VOCs, is predominantly from sources affecting indoor levels.
- $PM_{2.5}$ outdoor concentrations measured in Wabamun were similar to other CEHEAP communities who have completed this program and are below recognized guidelines.

An exposure model was developed to describe variation in personal exposure. Ten general factors were examined as potential causes of exposure variation: 1) gender; 2) reside at Paul First Nation 3) urban-rural location; 4) housing characteristics; 5) presence of a garage; 6) job status; 7) smoking characteristics; 8) time activity pattern; 9) outdoor concentration levels; and 10) indoor concentration levels.

The major findings were:

- Indoor variation accounted for nearly one-half of the variation in personal NO_2 exposure described by the model. Time activity was also an important driver of personal exposure while smoking and housing characteristics had minor effects. The most important factor within time activity appears to be the amount of time spent outdoors at work with higher exposure being associated with more outdoor work time. These results are similar to other CEHEAP studies except that there is not a significant rural-urban effect in the Wabamun area likely due to the fact there was not a large community within the program boundary.
- Overall, variations of indoor levels accounted for roughly one-half of the variation in personal SO_2 exposure explained by the model. Time activity was also an important factor affecting personal exposure. Age of the residence and having a garage may also have minor affects on SO_2 exposure.
- The variation in personal O_3 exposure described by the model was due to outdoor levels and time activity acting directly and indirectly through indoor levels. Smoking characteristics were found to be of relatively minor importance.
- Variation in indoor concentrations are the predominant factor affecting personal VOCs exposure (except nonane), while other factors were of minor relative importance. Outdoor concentrations did not have a significant direct effect on personal exposure but had a small indirect effect on indoor levels.
- Being a resident of Paul First Nation had a direct effect on personal exposure to nonane as well as influencing exposure from type of housing, time activity and indoor levels. Exposure to decane, methylhexane, *N*-propylbenzene, toluene were also indirectly influenced by being a Paul First Nation resident. Outdoor levels of these VOCs were low or not detected and indoor levels generally mirror rates of personal exposure. This indicates that exposure to these VOCs arise from consumer good or products or activities occurring within the homes of Paul First Nation residents.

- $PM_{2.5}$ exposure variations were very influenced by exposure to tobacco smoke and the presence of a garage attached to the home. Variations in outdoor concentrations were not an important consideration affecting variation in personal exposure to $PM_{2.5}$.

In addition to measuring exposure, the program examined a variety of indicators of health status. These included lifestyle behaviours, previous diagnoses and contacts with the health care system, in addition to objective measures of neurocognitive functioning and biomarkers of exposure and effect.

The major findings were:

- In both subgroups, urban/rural and Paul First Nation, over 60% had a body mass index (BMI) of 25 or higher. A BMI of 25 or higher can indicate the participant is overweight. In addition, the majority of the participants in both groups barely meet the amount of daily exercise recommended by Health Canada.
- Biomarkers of exposure for nicotine, mercury, arsenic, benzene and toluene were measurable (i.e. above laboratory detection limits), but all levels were unassociated with an increased degree of exposure. Biomarkers for xylene and ethylbenzene were not detected in any of the participants' samples.
- Three biomarkers of effect were evaluated for: serum IgE level, autoantibody level and lung function. High levels of serum IgE was related to cigarette smoking, history of asthma and wheezing near trees.
- A higher prevalence of positive autoantibodies results was determined but this prevalence may have been affected by a high proportion of females, individuals over 40 years and those experiencing illness at time of their participation. It should be noted that participants with disease specific autoantibodies were notified of their results and advised to consult their family physician for further information.
- Lung function of the participants was with in the normal range.
- No statistically significant differences in neurocognitive functioning were found between the program sample and reference populations.
- The most common self-reported diagnoses of chronic diseases in the sample was back problems (27.9%), other allergies not related to food (21.5%) and arthritis (20.9%). Over twenty percent (22.7%) reported no illness at the time of the survey.
- There is no evidence of either a significantly higher morbidity (period prevalence, frequency of visits) of asthma, bronchitis, and COPD in the Wabamun area, nor an increased risk of death from all causes, respiratory disorders, COPD, and major cardiovascular diseases in this area.
- There is evidence of an increased prevalence and frequency of visits for all respiratory disorders combined in the Wabamun and area. However, the mean visits of asthma and COPD are lower when compared to other CEHEAP communities.
- There is a difference in the Fee-For-Service physician visits for overall illness between the program participants and non-participants. Overall illness refers to any type of illness or access to any type of health care service.

1.4 Recommendations

1. **Establish ongoing monitoring of personal exposure levels to air contaminants.**

This program did not find evidence of elevated personal exposure to any of the contaminants which could affect a person's health. However, a recognized limitation of this program is the short period of time airborne contaminants are measured. A long term program of personal exposure monitoring is recommended to detect changes over time and varied weather and seasonal changes.

2. **Participate in the implementation of an organized approach to community exposure and health effects assessment in the province in support of long-term comparisons with other areas across the province.**

Strategic information gathering on community exposure and health across the province is key to evidence higher-based decision-making, managing health risks, and the development of health promotion, disease prevention, and exposure control strategies. Such information is also important to public concerns about air contaminants and health and for the development of health based air quality guidelines at a local, regional, and provincial level. Therefore, in collaboration with other agencies and organizations such as Alberta Health and Wellness, regional health authorities, Health Canada, and Alberta Environment, a co-ordinated system should be developed for the ongoing collection, analysis, and interpretation of air quality and health information. Such a system should be sustainable, cost-efficient, and should build on already existing resources without adding significant new costs.

3. **Adopt and promote the use of innovative methods and technologies such as personal exposure monitoring to further our understanding of the relationship between air quality and human health.**

The results of this program indicate that the ambient concentration of contaminants measured at monitoring stations is not a good predictor of individual exposure (i.e. personal exposure). In the study of health and air quality and in the development of human health-based air quality guidelines, it is important to go beyond traditional emission inventories and ambient air quality monitoring. Personal exposure monitoring is a method that can complement existing methods.

4. **Educate the general public about airborne contaminants and how to manage or reduce their exposure.**

This program indicated through its exposure modelling that the highest exposure to the measured contaminants was from indoor sources (e.g. tobacco smoke, off-gassing from consumer products, or combustion sources). While all the measured levels were low, improving the public's knowledge and understanding about how and where airborne contaminants may be found or created could reduce exposure regardless of source (indoor or outdoor).

2.0 Introduction

Human health concerns related to air quality have been raised by various stakeholder groups throughout Alberta including First Nations, environmental associations, governments, and the Clean Air Strategic Alliance (CASA). In response, a long-term, systematic approach to data gathering has been implemented in Alberta that will improve our knowledge about the link between the environment and human health. The approach combines two broad concepts in an integrated population-based environmental health framework: (1) the direct measurement of personal and population exposure to environmental factors, and (2) the epidemiologic surveillance of health outcomes in the population.

The development of the Alberta Community Exposure and Health Effects Assessment Programs (CEHEAP) is one method of improving our knowledge about the link between air quality and human health effects. The CEHEAP program was developed from existing scientific methodology and protocols and has been previously implemented in four (4) communities to date in Alberta. The four communities who have previously been involved in the program are Fort Saskatchewan, Fort McMurray, Lethbridge and Grande Prairie.

This program hopes to improve our understanding of the relationship between air quality and human health outcomes. These include:

- An understanding of the population and personal distribution of exposure to airborne chemicals and particulates; and
- An understanding of the relative contribution of various exposure sources and pathways to airborne chemicals (i.e. the relative contribution of outdoor and indoor air to the total exposure).

The Wabamun and Area Community Exposure and Health Effects Assessment Program (WACEHEAP) was initiated in response to public hearings conducted by the Alberta Energy and Utilities Board (AEUB) in 2001 - 2002 about coal-fired generating stations in the Wabamun area.[1] How these generating stations could potentially affect air quality and subsequently potential human health impacts was of particular concern. To estimate and clarify what the community concerns were, a random telephone survey (N=403) was conducted in July 2003. Respondents were asked to indicate their biggest health concern as a resident in the Wabamun area, desire for involvement in an exposure program, what information they would need to be communicated to them and their interest in being personally involved in the program. These survey results show that about 1 in 5 of the people surveyed have health concerns related to living in the Wabamun area.[2] Most of these concerns were centered on the potential impacts from the coal-fired power plants but people were also concerned about oil and gas operations in the area. A second self administered written survey was completed from October to December 2003 for members of community organizations to express their views on this issue. While the respondents of this survey were a self-selected group of concerned citizens, it reinforced what was learned from the telephone survey that there was a need for further investigation into the relationship between exposure to contaminants and health effects in the Wabamun area.[3]

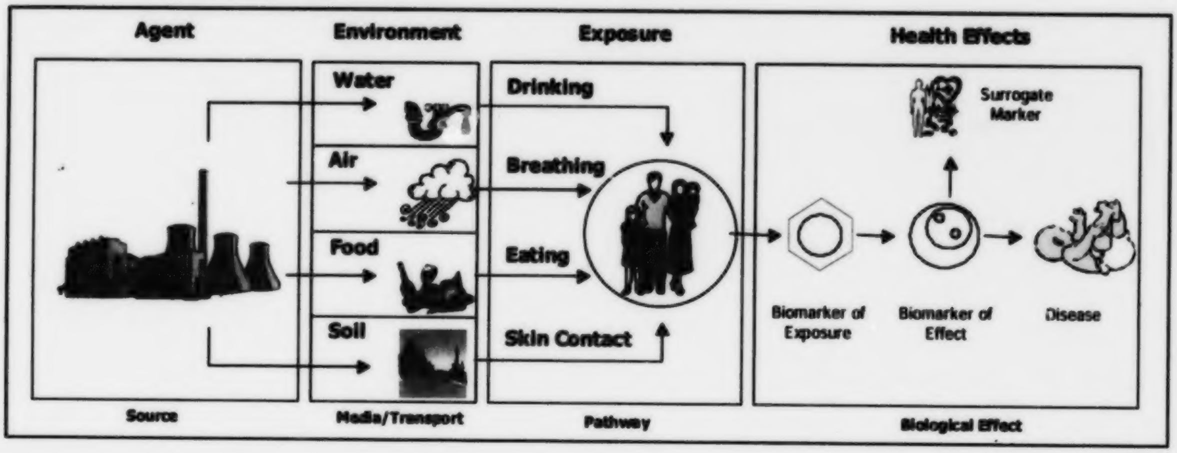
WACEHEAP is the fourth CEHEAP and is part of an ongoing effort by public health officials in Alberta to collect information on airborne contaminants and health concerns across the province. The information gathered in the Wabamun region will become part of a province wide database and will allow comparisons of human exposure and levels of airborne contaminants across various communities in Alberta.

WACEHEAP was implemented using scientific methodologies and protocols that have evolved over many years and have been proven effective in previous assessment programs.[4]

3.0 Background and Rationale[1]

In general, exposure can be defined as any contact between a substance, biological agent, or radiation with an individual or community. We are all exposed to low levels of contamination in the air we breathe, the food we eat, the water we drink, and the consumer products we use. Contaminants can interfere with the normal biological functions, causing effects ranging from subtle biochemical changes to clinical disease and even death. Figure 1 displays this concept of a continuum from source of contamination to the final health effect, which is a basic feature of all contemporary risk models.

Figure 1: Continuum of Exposure



Determining the risk posed by environmental contaminants to populations requires knowledge about the following fundamental components:

- Source(s) of contaminants;
- Transport of agents in the environment;
- Exposure of individuals and communities to chemicals;
- Dose received by those exposed (biological markers of exposure);
- Early biological effects resulting from the dose (biological markers of effect); and
- Overt health effects (clinical disease, death).

The output of each component in the chain of events serves as input to the next. The lack of information on any one component thus impairs our ability to make accurate assessments of the associated population health risks. Our knowledge about the source and transport of chemicals and other agents in the ambient environment is increasing as the result of environmental monitoring programs; however, there is a need to integrate these data sources with information on population exposure, biological markers, and health effects. This is very important in achieving new health-based protection levels.

In dealing with population health outcomes, which may be attributable to long-standing exposures to low-levels of contaminants, we are confronted with the difficult and complex problem of chronic health effects. A number of conditions, such as cancers, disorders of the cardiovascular system, neurological disease, chronic respiratory ailments, and many other diseases, have important environmental, behavioural, social, and genetic links. The causes of these conditions are multi-factorial in nature. Other characteristics, such as multistage development, long induction time, and the absence of information on individual and population exposure, make progress in chronic disease prevention slow and tenuous. In order to be able to address these issues, more than ever, there is a need to look beyond one-time epidemiologic studies.

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[1] This section previously published in The Grande Prairie and Area Community Exposure and Health Effects Assessment Program: Final Report, 2002.

Environmental health surveillance is a tool that can be used to gather data and information on the health of people for the purpose of tracking and detecting trends and associations among a broad range of environmental and health related variables. The process consists of an on-going, systematic collection, analysis, and interpretation of selected data on health outcomes, environmental quality parameters, and population exposure. In addition, data on behavioural, lifestyle, social, economic, and other confounding variables are also considered.

The Alberta Community Exposure and Health Effects Assessment Program protocol was developed to obtain measures of exposure across the continuum of exposure, including measures of contaminants in the environment, the quantity of contaminants to which an individual is exposed through these sources, and finally biological measures of exposure, effect and disease. Further details regarding the program protocol can be found in the Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Methods Report.

4.0 Program Objectives

The Wabamun and Area Community Exposure and Health Effects Assessment Program's primary objectives were to:

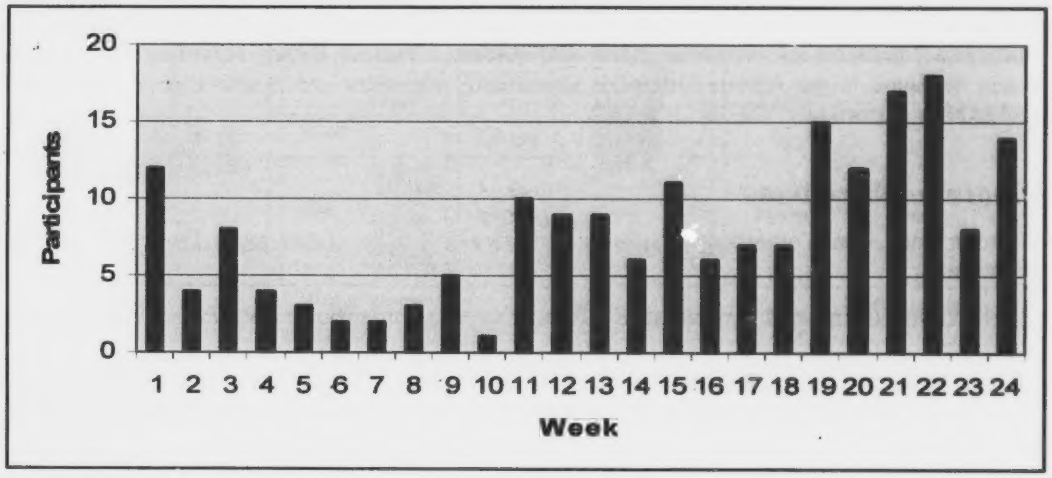
- Describe the sample and personal distribution of exposure to airborne chemicals and particulates through:
    - Estimation of the sample distribution of selected airborne chemicals and particulates; and
    - Characterization of the personal variation of exposure as a function of individual activity patterns.
- Quantify the relative contribution of indoor and outdoor air on personal exposure.
- Describe associations between exposure to airborne chemicals and human health effects by analyzing the occurrence of relationships between selected exposures, biomarkers and health outcomes.

5.0 Program Method and Protocol

5.1 Recruitment and Sample Selection

Data were collected during a period of approximately 24 weeks (May 17, 2004 to November 2, 2004) with an average rate of eight individuals per week, for a total sample of approximately 209 individuals. Unpaid volunteers over the age of 18 years were recruited from the cities of Spruce Grove, Stony Plain, and towns of Wabamun, Devon and Thorsby. In addition, volunteers were recruited from Paul First Nation and rural areas surrounding these municipal communities. Figure 2 shows the number of participants recruited by week.

Figure 2: Participants Recruited by Week throughout Program Period



Recruitment

Participation in the program places significant demands on the participants. As a result, the protocol recommends that recruitment of volunteers is preferable to a complex sampling design that would require participants to be solicited for participation. Considerations included the following:

- Participation rates would be expected to be so low as to defeat the purpose of a complex sampling design;
- Self-selection biases are not likely to affect exposure rates; and
- Cost would be substantially reduced.

To recruit participants multiple routes and opportunities were capitalized on. Typical media resources or vehicles such as local television stations, rural and urban newspapers and radio were targeted to solicit participants by transmitting an overview of the program. In addition to those traditional routes, "top down" and "grassroots" recruitment strategies were used. Top down recruitment refers to attempting to recruit by community leaders such as municipal government or community leaders. This tactic allows for community advocates to champion the program and encourage participation. Presentations were made to municipal council meetings to not only inform them about the program but also to try and recruit "high-profile" municipal members.

Grassroots recruiting is the opposite of the top down tactic in that it attempts to contact potential participants on a direct individual level. A variety of modes were used including contacting the approximately 200 respondents who expressed interest from the Community Telephone Survey conducted in July 2003. Presentations, information sessions and brochures were also available or held at local farmer's markets, trade shows, and public community buildings and at larger employers within the Wabamun program area. As these methods were not providing sufficient number of participants, two additional approaches were implemented. These two additional approaches were randomized direct telephone calling and door to door recruitment.

An important mode of finding participants from the Paul First Nation was to use a "snowballing" technique. This is where volunteers already involved in the program are asked to identify other individuals known to them who may be interested in participating and permission to contact them. The participant is also encouraged to speak to them and provide them with the program materials.

Sample Selection

The targeted sample size was 300 participants from within the Wabamun program boundaries. This proposed sample would be split into three fractions: (1) 100 participants from urban areas; (2) 100 participants from rural areas and (3) 100 participants from the Paul First Nation. All volunteers will be older than 18 years of age and the objective would to have a sample that follows typical age-gender stratification patterns within each of the 100 portions. This means 50% of the sample ideally will be female and 50% male with approximately 10% of the sample in each of following ten age categories: 18-24; 25-29; 30-34; 35-39; 40-44; 45-49; 50-54; 55-59; 60-64 and 65 or older. As participants are self selected to be volunteers it is important to note that this sampling pattern may not be achievable.

Children (<18 yr.) are excluded from the sample for the following reasons:

- Very young children cannot carry the personal exposure air monitors;
- Children might not be able to provide reliable time-activity data;
- Ingestion may be an important route of exposure to particulates for children that could not be evaluated within the parameters of the program;
- Children are likely to have higher exposures to particles and chemical constituents than adults because of their activity patterns; and
- Older children who could carry the monitor might be less likely than adults to wear it because it would interfere with normal activities.

A separate child component was piloted for the Wabamun and Area Community Exposure and Health Effects Assessment Program. Children who volunteered did not wear any personal exposure monitors, complete any of the surveys, neurological components or provide any lung function assessments. The children submitted blood, urine and hair samples for biomarker of effect and exposure analysis equivalent to adult volunteers. These results will be discussed in the appendices of this report.

5.2 Program Design

Several countries as well as the World Health Organization (WHO) are implementing exposure and health effects assessment approaches to address human health concerns related to environmental and other (e.g., occupational) factors. The Alberta Community Exposure and Health Effects Assessment Program is a complete study protocol that was designed to ensure that the results of exposure assessments conducted in Alberta are comparable. This approach provides information for comparison purposes and contributes toward a province-wide source of information on personal exposure measures. The protocol is modeled after an approach to exposure assessment developed by the US Environmental Protection Agency known as the TEAM approach.[5] The Program was designed to produce baseline population exposure and health outcome data through a population exposure assessment conducted in conjunction with a population health assessment. Previous studies have been completed to develop and test data collection methods for exposure assessment, develop and test data collection methods for the collection of additional data, and examine program logistics. The results of these studies are described in separate reports.[6,7,8,9,10,11] This report provides the results of the implementation of the Program protocol in Wabamun and surrounding areas.

Contaminants Measured

The selection of the following contaminants measured was based on three criteria: (1) local concern of these air contaminants; (2) national initiatives have placed them as a priority for reduction, have exposure limits and monitoring requirements; and (3) availability of technology to accurately quantify the contaminant. Specifically data were gathered on the following contaminants:

- Nitrogen dioxide (NO_2) – a gas that results from combustion; sources include vehicular exhaust, gas stoves, tobacco smoke, kerosene heaters, wood-burning stoves and fireplaces, and gas pilot lights.
- Sulfur dioxide (SO_2) – a gas produced by several industrial processes; sources include vehicles, outdoor air, unvented kerosene heaters, and wood-burning heaters and stoves.
- Ozone (O_3) – a gas created through the interaction of hydrocarbons, nitrogen oxides, and sunlight; ozone is primarily found in outdoor air, although sources may also include residential electronic air cleaners, negative ion generators, photocopy machines, deodorizers, germicides, and some aerosol sprays.
- Volatile organic compounds (VOCs) – a number of compounds that are carbon-based vapors and gases, many of which are produced from chemical reactions; sources include air fresheners, moth balls, polyurethane floor finish, synthetic fabrics, furniture polish, latex paint, floor wax and wax strippers, shoe polish, solvents, particle board, floor and carpet adhesives, fluorescent lighting, and tobacco smoke.
- Inhalable particulates – microscopic particles that remain floating in the air and can enter the respiratory system; sources include tobacco smoke, kerosene heaters, home renovations, fabric lint, wood stoves or fireplaces, humidifier deposits, and dander.
- Polycyclic aromatic hydrocarbons (PAHs) – compounds that can be formed by incomplete combustion, some of which exhibit carcinogenic effects in humans; sources include gas flaring, teepee burners, automobile exhaust, and any type of natural (e.g., forest fires) or unnatural burning; indoor sources of may include fireplaces, tobacco smoke, and any other household smoke sources (e.g., burnt toast).

Passive Air Sampling

All volunteers were required to wear passive sampling air monitors in their personal breathing zone continuously for a 7-day period[2]. The air-sampling monitors were analyzed for levels of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and a wide range of volatile organic compounds (VOCs) such as benzene e and toluene. Similar air samplers were located inside and outside of participant's homes to provide measures of contaminants in and around their personal living space.

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[2] In the original study protocol, Alberta Oil Sands, four consecutive 24-hour samples were collected from each volunteer. This was modified for subsequent CEHEAP studies to one continuous, 7-day sample to lower the method detection limit and to accommodate field logistics. A 7-day sample also provided a more representative exposure measure as it spanned both weekday and weekend activities for each volunteer.

Polycyclic Aromatic Hydrocarbon (PAH) Air Sampling

Approximately 15% (1 in 7 volunteers) of the sample were requested to have polycyclic aromatic hydrocarbon (PAH) monitoring equipment located inside and outside of their homes continuously for a 7-day period to gather data on the levels of these contaminants in and around their personal living space.

Additional Data Sources

Table 1 shows the various components and sources of data used in the program. In addition to the exposure sampling listed above, all volunteers were requested to complete the following:

- Review and sign a consent form outlining the participant's involvement in the program;
- A series of neurocognitive tests;
- Two health and exposure related questionnaires, provided to the participants to complete at their convenience during the 7-day period of participation;
- One sample of blood and one 12-hour composite sample of urine;
- A sample of hair and completion of hair washing survey;
- Assessment of lung function including a spirometry session and interviewer-administered respiratory health survey and;
- A diary of personal activities throughout the 7-day period of participation.

Table 1: Components of the Program

Component	Media or Source of Data	Purpose
Characteristics of the Sample	Vital Statistics Other Demographics	General information to characterize the sample.
	Lifestyle behaviors	Sections of the questionnaire identified individual smoking habits, weight, height, nutritional intake, and physical activity levels.
	Time Activity Diary	The time activity diary identified potential routes of exposure in daily activities.
Exposure Measurement	Personal Exposure Monitors: Passive samplers Particulate/PAH samplers	Measures of the actual exposure levels of each participant during a regular week, using personal, indoor, and outdoor air monitors. Measures of exposure for particulate matter and polycyclic aromatic hydrocarbons (PAHs) were collected for a sub-sample.
	Ambient Station Data	Ambient station monitors were also set-up for the duration of the program period.
	Other Sources of Exposure: Household sources Work sources Dietary sources	Sections of the questionnaire identify potential sources in the home and work environments, and identification of potential dietary sources of exposure.
Biomarkers of Exposure	Blood	Analysis included measures of nicotine, total mercury and arsenic.
	Urine	Analysis included measures of metabolites of the BTEX compounds (benzene, toluene, ethylbenzene, m-, p-, and o-xylene). In addition, total arsenic and arsenic speciation.

Component	Media or Source of Data	Purpose
	Hair	Analysis included measures of mercury.
Biomarkers of Effect	Autoantibodies	Analysis included immunofluorescence microscopy to detect autoantibodies, which indicate elevated immune system reaction.
	Immunoglobulin gamma E (IgE)	High levels of IgE are associated with an increased incidence of diseases including bronchial asthma, allergic rhinitis, and eczema.
	Lung Function	Spirometry was used to measure the individual's lung capacity and volume during the exposure-monitoring period.
	Neurocognitive measurement	Neurocognitive tests to determine the potential impact of chronic exposure on neurocognitive functioning.
Measures of Health Outcome	Health Care System Records	Records of participant contacts with the health care system in the recent past identify health conditions not captured by the questionnaires. Diagnosis rates were compared to control communities.
	Questionnaires	Sections of the questionnaire identified general, occupational, emotional, and psychological health.
		Sections of the questionnaire identified previously diagnosed health problems.

5.3 Program Logistics

Science Team

A science team was established to oversee the design and implementation of the program protocol. The science team was responsible for:

- Training field staff including the project co-ordinator and field monitoring teams;
- Defining any alterations to the original protocol to address issues unique to the Wabamun area; and
- Statistical analysis of the data and preparation of the final report.

Field Staff

The project co-ordinator was responsible for selecting and screening participants, booking appointments for the field monitoring teams, maintaining the sampler inventory, and co-ordinating the flow of samplers to the laboratory for analysis. In addition, the field co-ordinator was responsible for co-ordinating the flow of sampling time information and respondent data, ensuring that all aspects of the program are administered to each of the participants, and ensuring entry of all data electronically into various databases programs.

Field monitoring teams consisted of two trained personnel who were responsible for placing the samplers in an appropriate location in each participant's home, collecting spent samplers, and recording various sources of data. A multi-day training session was held for the field monitoring teams. Classroom training consisted of a review of the program and the requirements for successful completion. Each team member was required to practice and demonstrate the ability to correctly handle and locate samplers in a participant's home.

Field Operations

Each participant was requested to complete a standard protocol that included participation in all aspects of the program. The protocol requested each volunteer to visit the program office for initial testing. Each participant was required to sign a consent form and requested to provide their Personal Health Number (PHN) before beginning. Additional screening criteria included:

- Availability for an interview at the program office to provide the required preliminary information and complete a set of neurocognitive tests; and
- Availability that week to allow field monitoring teams to deploy and retrieve the air monitoring equipment at the beginning and end of the 7-day period.

The project co-ordinator explained the program in detail, stressing the requirements of complete participation. Samples of the monitoring equipment and typical placements were used as part of the explanation. After answering any questions about the program, the co-ordinator gave the participant time to read the consent form. If necessary, the co-ordinator read the consent form to the participant. At the completion of the data collection period, consent forms were separated from the other documents, sorted by identification number, and filed in secured storage. Since these forms contain names and linkages to other data, they were kept separate from other information to assure the confidentiality of respondent information.

After the initial screening was completed, the monitoring team appointment booked, and all forms signed, the participant was required to complete tests of visual acuity and colour-blindness, a respiratory health survey, and a variety of tests of neurocognitive functioning. Two questionnaires that request information about the individual's home, lifestyle, diet, and health were provided to each participant to complete during their participation in the program. The individual was also required to schedule an appointment at the laboratory to provide a blood sample and a 12-hour urine sample.

The field monitoring teams deployed air-sampling devices at the participant's home that remained in place for the 7-day sampling period. The field monitoring teams retrieved the air monitoring equipment at the end of the sampling period.

Field monitoring teams operated in pairs to ensure safety and improve accuracy. Each team received a list of participants who had completed the initial testing phase described above and the appointment times. The teams were responsible for contacting the participant at the previously arranged appointment time to place the samplers in the home and on the individual. On arrival, the monitoring teams provided details about the equipment being placed in the home and explained what to do if there were problems with the equipment. The monitoring teams also provided additional details about the time activity diary that the participant was requested to complete: participants were asked to record their activities throughout the 7-day sampling period. At the conclusion of the 7-day period, the field monitoring teams reviewed and collected the time activity diaries, self-administered surveys, and answered any final questions.

Data Entry and Analysis

All information collected by the field staff was returned to the program office at the end of the day. The project co-ordinator reviewed it to verify completeness and, if necessary, follow-up with the participant to complete any missing information. Data was entered by the project co-ordinator. The project co-ordinator then sent the electronic and paper files to Alberta Health and Wellness where a database co-ordinator verified data entry and cleaned records. Once data entry was completely verified, the electronic files were compiled and merged as necessary into a database for analysis. All data components were made identifiable by the arbitrarily assigned participant identification number only; other identifiable information was stripped from the records to ensure confidentiality of the results. Data analysis was then conducted by the science team at Alberta Health and Wellness offices using *SAS* and *SPSS* statistical packages.

5.4 Exposure Monitoring Procedures

The field-monitoring protocol was designed to collect sufficient samples to characterize the exposure of a representative sample to nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), volatile organic compounds (VOCs), and inhalable particulates (up to 2.5µm in aerodynamic diameter). Each compound of interest was monitored for a 7-day period in three locations: personal (in the participant's breathing zone), indoors (in an appropriate location inside the participant's home), and outdoors (in an appropriate location outside the participant's home). To enhance quality assurance and quality control procedures the field teams also deployed "blanks", or unexposed samplers. Blanks were handled and analyzed in an identical manner as the other air monitors, but, unlike the other monitors, they were not exposed to the environment.

Meteorological data was obtained from the West Central Airshed Society's website at www.wcas.ca. Specifically, three monitoring stations within the program area were utilized, Wagner, Genesee and the Meadows. At these stations, measurements are taken regularly include wind speed, wind direction, temperature, and relative humidity.

Monitoring Equipment

Passive Air Monitors

Nitrogen Dioxide (NO_2): A passive air monitor was used for measuring nitrogen dioxide. The clip-on air monitor contains a chemical adsorbent that collects nitrogen dioxide indicators by passive diffusion.

Sulfur Dioxide (SO_2): A passive air monitor was used for measuring sulfur dioxide. The clip-on air monitor contains a chemical adsorbent that collects sulfur dioxide indicators by passive diffusion.

Ozone (O_3): A passive air monitor was used for measuring ozone. The clip-on air monitor contains a chemical adsorbent that collects ozone indicators by passive diffusion.

Volatile Organic Compounds (VOCs): A passive air monitor was used for measuring a variety of VOCs. The clip-on air monitor contains a chemical adsorbent that collects various VOCs by passive diffusion.

All four passive air monitors were designed to be worn in the participant's breathing zone to measure personal exposure. The participants were encouraged to continue normal activities while wearing the monitor. During activities such as sleeping or showering, however, the sampler was to be kept as near to the person as practical while protecting the sampler from damage and high humidity environments.

One of each type of sampler was deployed inside and outside the participant's home using a stationary stand constructed to house and shelter the monitors during the 7-day exposure period. The air monitors were attached to identically constructed indoor and outdoor stationary stands approximately one (1) metre above the floor or ground. The outdoor passive air monitoring stand has a rain shield approximately 30cm in diameter for shelter.

The method detection limits (MDL) of the passive samplers were based on field blanks and the limit of quantitation of the laboratory analysis. The detection limits for VOCs were based on the laboratory limit of quantitation (150 ng/sampler) when more than 90% of the field blanks were less than the limit of quantitation and are indicated by an asterisk in the table. For the other compounds, the detection limit was based on three standard deviations of the field blank levels and may vary slightly between the batches of samplers through the program. The detection limits for the compounds investigated (assuming a 7-day sample) are listed in the third column of Table 2. Columns 4 to 6 in the table show the fraction of the measurements that were below the detection limit. Despite not being measurable, failure to detect a particular component remains useful in characterizing community exposures.

Table 2: Summary of Passive Sampler Detection Limits

Sampler Compound	Sample Rate (ml/min)	Detection Limit ($\mu g/m^3$)	Fraction of samples less than MDL		
			Personal	Indoor	Outdoor
NO_2	120	2.1	1.1%	0%	1.7%
SO_2	218	1.1	48.4%	62.3%	1.7%
O_3	24.5	0.82	0%	0%	0%
Hexane	32	2.2	50.0%	62.2%	95.8%
3-Methylhexane	28.9	0.51*	5.7%	29.0%	81.3%
Benzene	35.5	0.42*	0%	2.6%	7.8%
Heptane	28.9	0.51*	12.0%	28.0%	77.6%
Toluene	31.4	2.6	3.1%	5.7%	88.0%
Octane	26.6	0.56*	7.3%	14.0%	88.0%
Ethylbenzene	27.3	0.55*	2.1%	14.0%	87.5%
m-, *p*-Xylene	27.3	1.0	1.0%	5.7%	63.5%
o-Xylene	27.3	0.55*	3.6%	14.5%	83.9%
Nonane	24.6	0.60*	27.1%	41.5%	96.9%
Decane	23.1	0.64*	9.9%	17.6%	73.4%
Limonene	30	0.50*	0.5%	1.6%	67.7%
N-propylbenzene	24.6	0.60*	31.8%	46.1%	90.6%
N-butylbenzene	22.4	0.66*	88.5%	84.5%	55.2%

* *Detection limit based on laboratory limit of quantitation (150 ng/sampler) assuming 7-day sample period.*

Active Air Monitors

For measurement of respirable particulates such as particulate 2.5µm and PAHs from indoor and outdoor environments at the participant's home, the stationary indoor and outdoor air particulate pumps were used to house particulate sampling heads and filters. The particulate sampling heads were oriented in a position that avoided particle deposition due to gravity and were attached to the particulate pumps approximately one (1) metre above the floor or ground. Before and after exposure monitoring, the particulate filters were weighed, and the information was recorded along with the filter identification numbers for analysis purposes after the 7-day exposure period.

Sampler Placement Strategy

All sampler locations were determined during the initial visit to each home. Locations were selected after carefully determining the layout of the home, based on the daily habits of the participant, the type of dwelling (home, apartment, etc.), and the outside layout of the yard or grounds. Samplers were placed in the main living area of the participant (the room in which the participant spends the most time while awake), ensuring that the samplers were at least two metres away from exterior doors, windows, and ventilation registers.

The protocol specifies that the participant's backyard is the preferred location for outdoor sampling and that the monitors should not be located within one metre of trees and bushes or within five metres of any type of air vent. For second floor apartments, a "yardarm" was deployed from a window or balcony to support the sampling devices. If a yardarm was not possible, the protocol considers collection of samples at ground level acceptable for second floor apartments. Non-ideal situations required some reasonable compromises, but were identified by the field teams for consideration during data analysis.

5.5 Neurocognitive Functioning

Participants were requested to complete a series of computerized neurobehavioral tests using the Neurobehavioral Evaluation System (NES2)[12] software installed on an IBM compatible computer. Participants were informed that they could stop and ask questions or, if absolutely necessary, leave the premises at any time, and they should not feel pressured to continue to respond. Prior to completing the series of neurobehavioral tests, subjects were given a brief explanation of how they were expected to respond (e.g., what keys to use). Subjects were also given visual tests to ensure normal visual acuity and colour vision (required for the colour-word test). A pre-test questionnaire was completed to identify the subject's general well-being and current health status.

The NES2 tests administered included: finger tapping test; associate learning test, switching attention test, mood scales, continuous performance test, simple reaction time test, symbol digit test, pattern comparison test, pattern memory test, serial digit learning test, colour-word test, vocabulary test and delayed associate recognition test. A symptoms questionnaire was also included in the NES2 program to collect information on symptoms that are often associated with exposure to neurotoxic agents. The Verbal Digit Span is a section of the Wechsler Memory Scale – Revised was also administered to each participant as an assessment of auditory processing. These activities were all administrated by a trained interviewer

5.6 Questionnaires

Two questionnaires were given to each participant following the completion of the neurocognitive functioning tests for completion at their convenience during the 7-day testing period. The first questionnaire, the Demographic and Exposure Questionnaire, was designed to collect information about participant demographics, occupational health, and their work and home environments, including potential sources of contaminants.

The second questionnaire, the Health Habits and Diet Questionnaire, was designed to collect a variety of health indicators, including mental and physical health, physical activity levels, and nutritional intake. The questions on nutrition attempt to characterize actual nutrition levels using the amounts dictated by the Canadian Food Guidelines. Two standardized scales of general health were included in The Health and Nutrition Survey and the General Health Questionnaire (GHQ). Both questionnaires are well validated and documented tools for assessing health. The GHQ assesses psychological well-being and additional measures from the National Population Health Survey, conducted by Statistics Canada, were also included to provide information about physical activity level.

5.7 Biological Tests

A laboratory technologist from DKML extracted a sample of each participant's blood and hair for testing. Biomarker analysis was performed by the Centre for Toxicology. The participant was also requested to submit a 12-hour urine sample. Biological samples were generally obtained during the final day of the sampling period.

5.8 Health Records Analysis

All participants were requested to provide a Personal Health Number, and give written consent for its use in retrieving administrative information for use in the evaluation. The primary data sources used for analysis were hospital discharge summaries, physician billing claims, and the Alberta Vital Statistics Death Registry. These data were used to identify health status of and mortality rates of the program participants and of the Wabamun and area sample.

6.0 Characteristics of the Sample

The Wabamun and Area Community Exposure and Health Effects Assessment Program involved 209 residents from Wabamun and the surrounding area. Within this area are a number of communities other than Wabamun including Devon, Spruce Grove, Stony Plain, Calmar, Thorsby and Warburg. The overall program area is shown in Figure 3. Figures 4 to 6 show specific communities and the participation distribution.

Figure 3: Overview of Wabamun Program Area

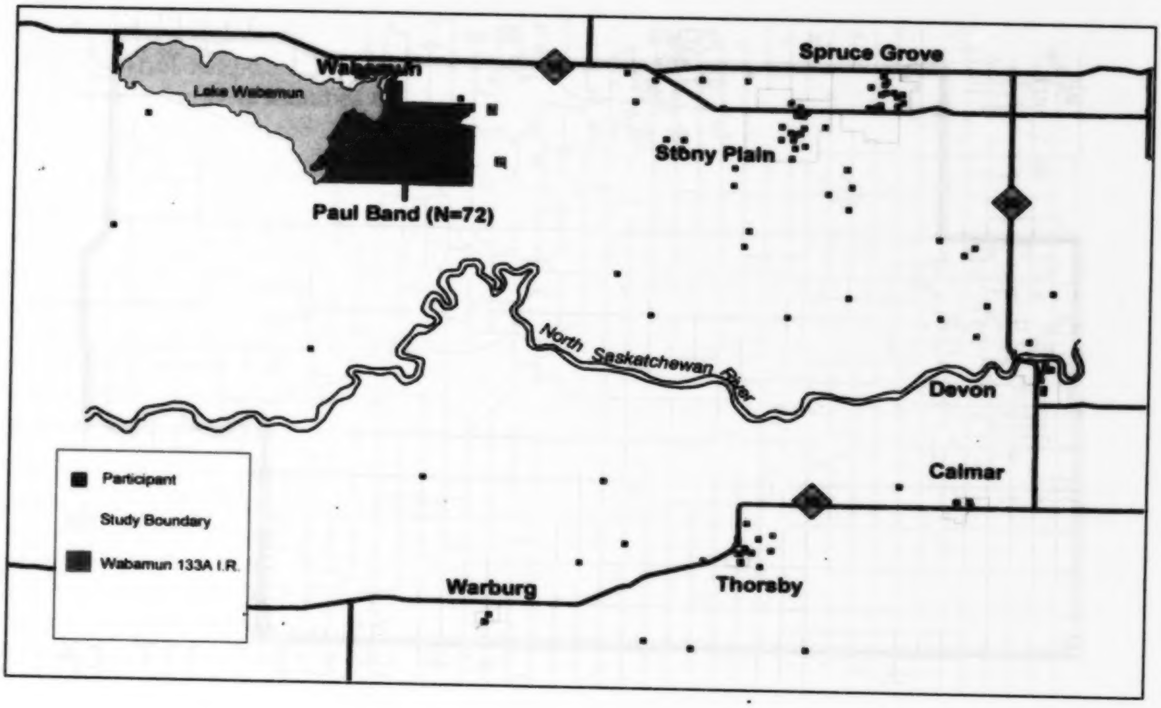
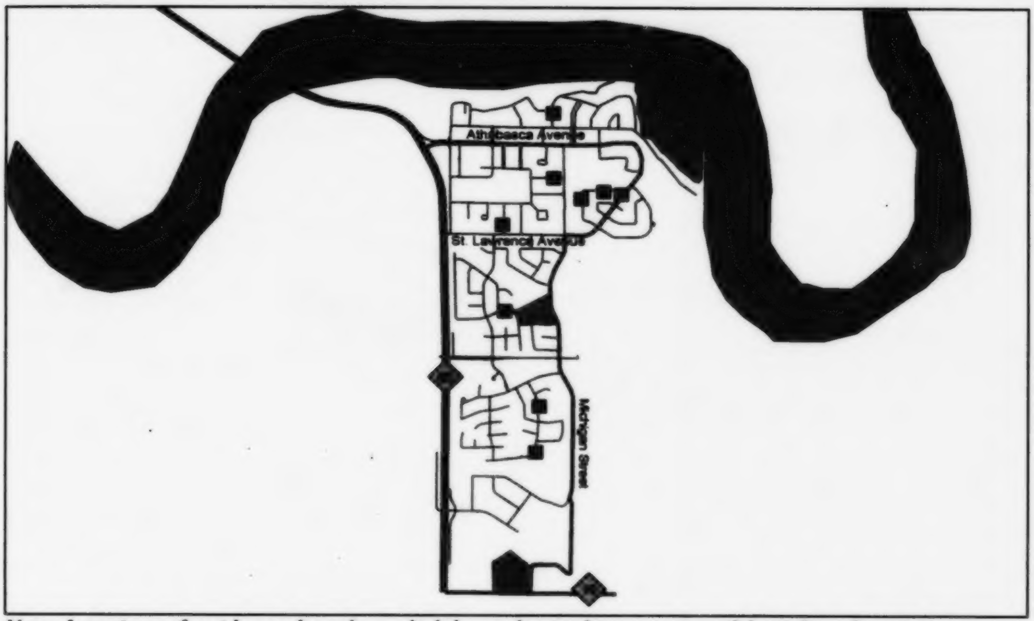
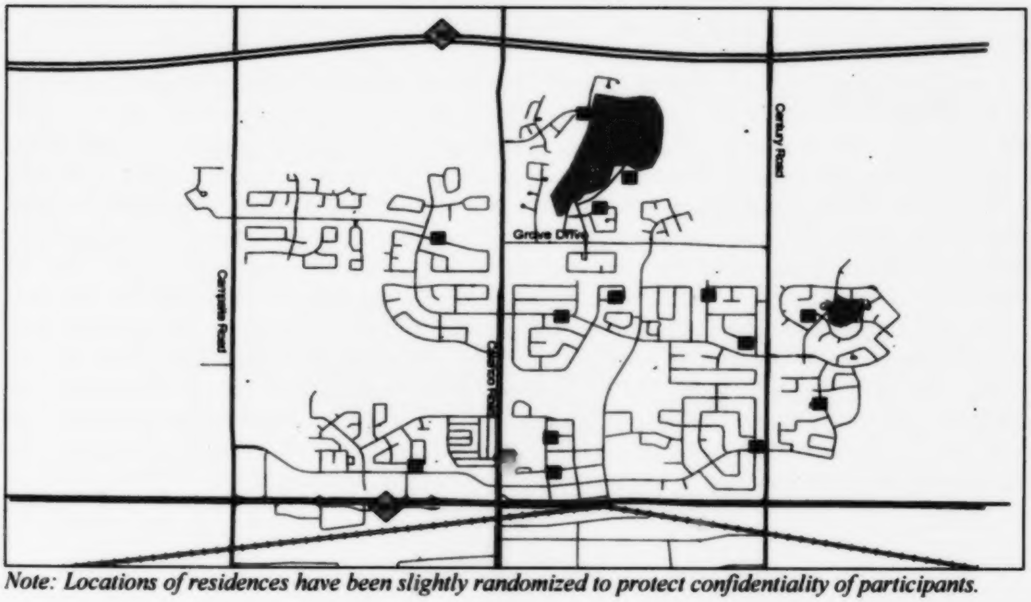


Figure 4: Distribution of Devon Participants



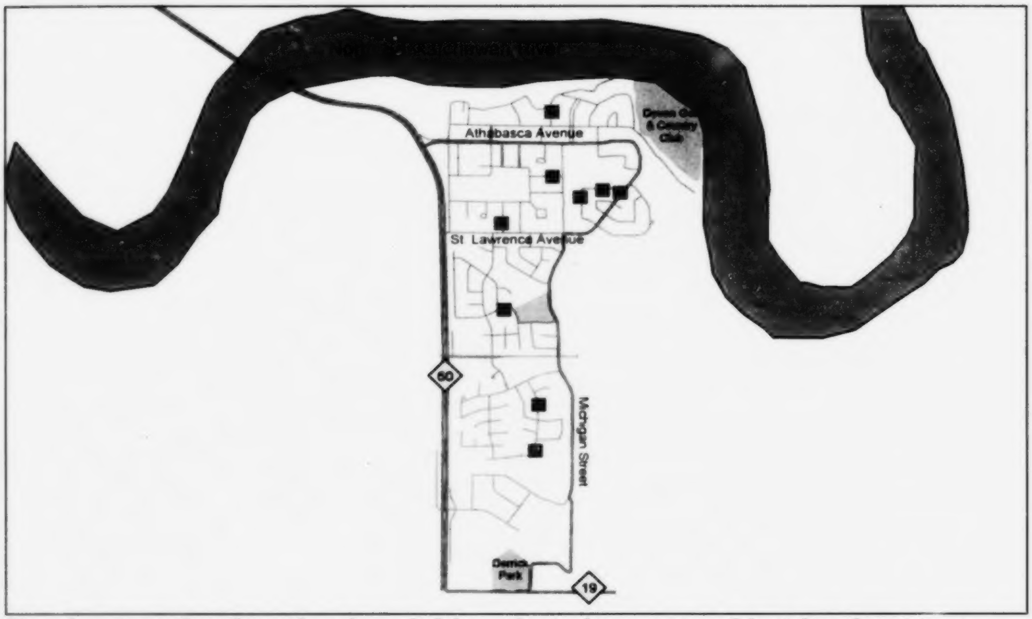
Note: Locations of residences have been slightly randomized to protect confidentiality of participants.

Figure 5: Distribution of Spruce Grove Participants



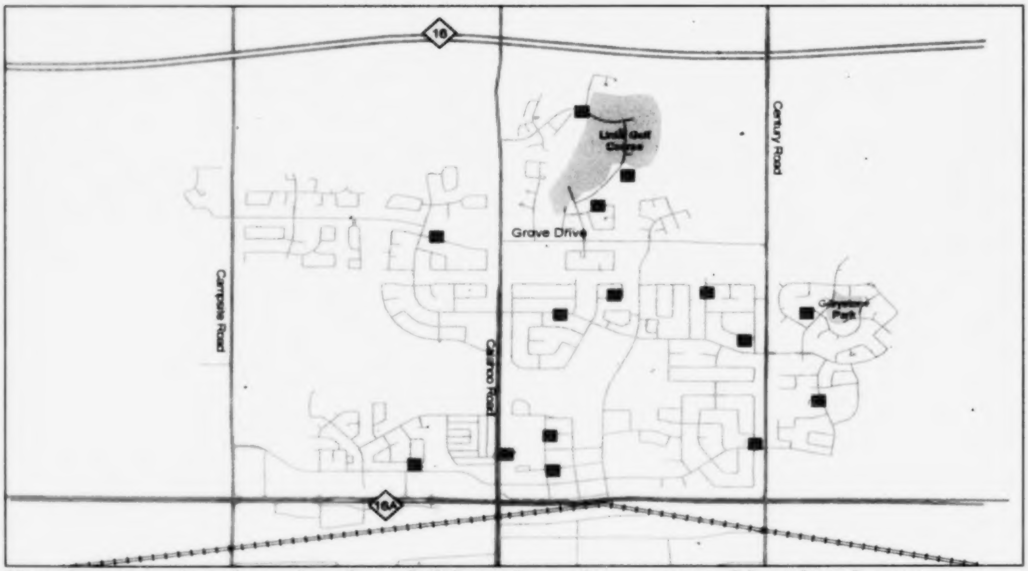
Note: Locations of residences have been slightly randomized to protect confidentiality of participants.

Figure 4: Distribution of Devon Participants



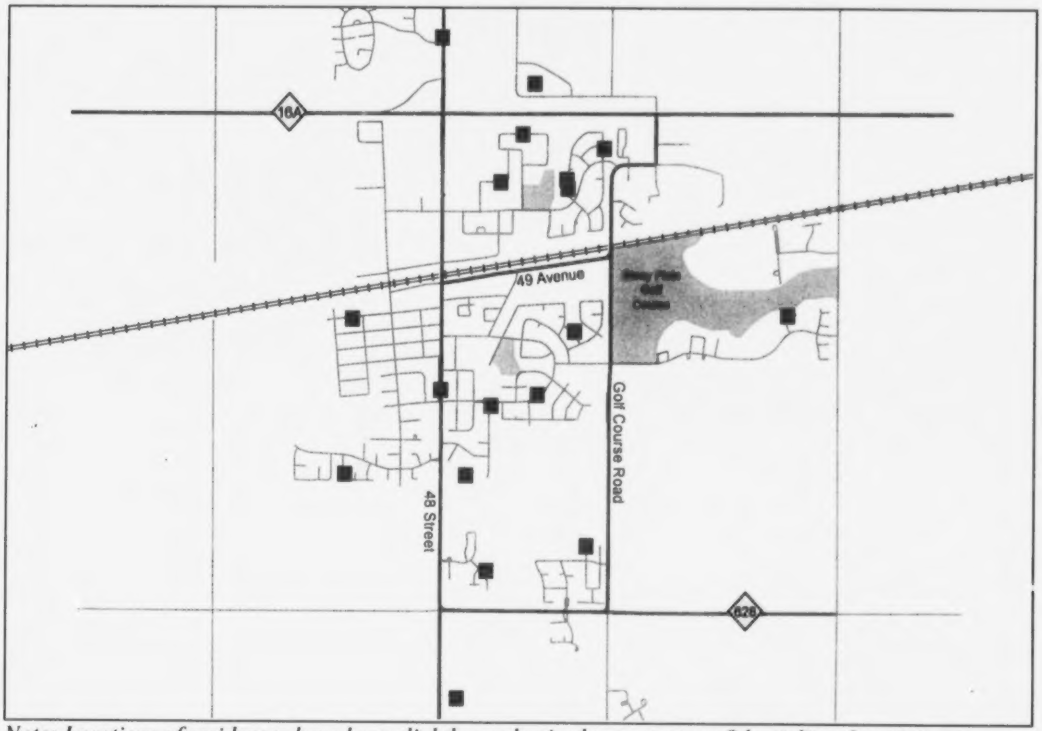
Note: Locations of residences have been slightly randomized to protect confidentiality of participants.

Figure 5: Distribution of Spruce Grove Participants



Note: Locations of residences have been slightly randomized to protect confidentiality of participants.

Figure 6: Distribution of Stony Plain Participants

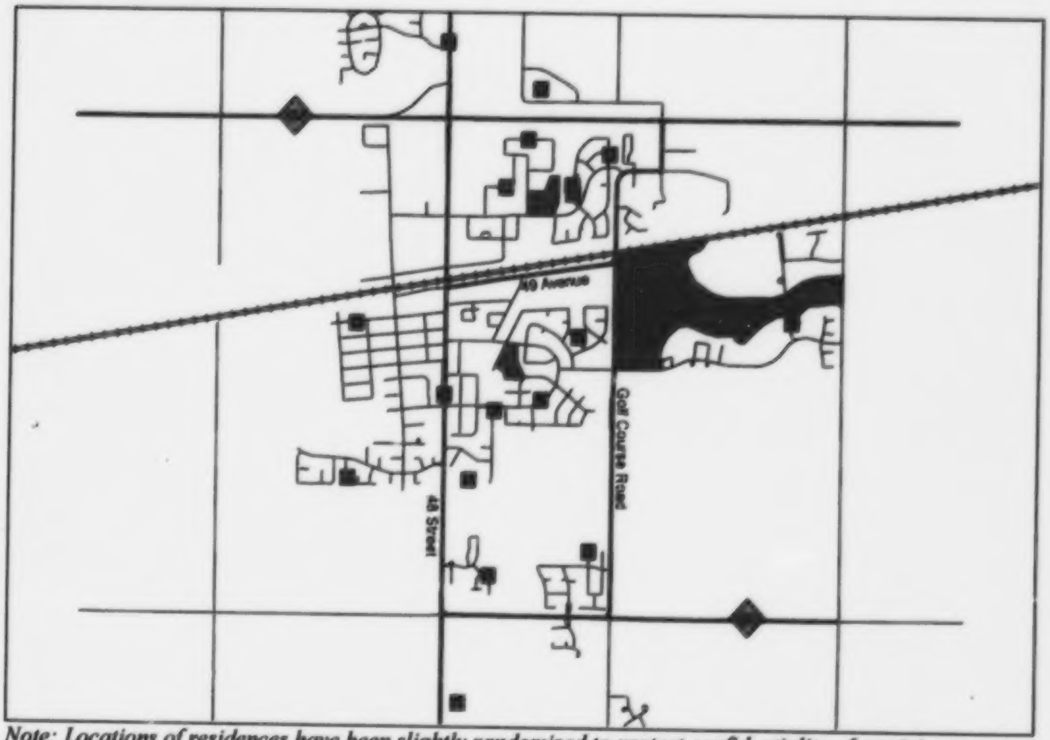


Note: Locations of residences have been slightly randomized to protect confidentiality of participants.

6.1 Sample Size

To conduct statistical comparisons between certain subgroups, the original protocol recommended a minimum sample size of 300 participants with 100 participants each from urban and rural areas within the program area and 100 participants from the Paul First Nation. A total of 209 people volunteered initially to participate in the assessment, however thirteen (13) people formally withdrew from the program and any information collected from them was not utilized in the preparation of this report. As the recommended sample size was not reached, the urban and rural participants were blended into one subgroup with participants from Paul First Nation in a second subgroup. Table 3 indicates the total number of participants in the urban/rural areas was 123 and 73 participants from Paul First Nation. However, only 151 participants in total, 101 and 50 respectively, completed all components of the program. Table 3 also shows the number of adult participants who completed various components of the program. As will be demonstrated in the results presented, all data available for each component was utilized even though the participant may not have completed all parts of the program.

Figure 6: Distribution of Stony Plain Participants



Note: Locations of residences have been slightly randomized to protect confidentiality of participants.

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Table 3: Number of Participants Completing Each Program Component

Program Component	Number of Participants (Urban/Rural)	Number of Participants (Paul First Nation)	Total
Total Number in Program	123	73	196
Passive Exposure Assessment	121	72	193
Particulate Exposure Assessment	37	7	44
Completed Demographic Questionnaire	110	62	172
Completed Health Questionnaire	110	62	172
Completed Neurocognitive Assessment	121	69	190
Completed Respiratory Health Survey	120	69	189
Completed Spirometry Tests	111	69	180
Completed Time-Activity Diary	118	63	181
Total with Complete Data	101	50	151

6.2 Age and Gender

Adult Participants

The urban/rural sample subgroup was 75.5% female with an average age of 50.5 years (N=110, SD=12.3). The sample of participants from Paul First Nation had an average age of 39.1 years (N=62, SD=11.4) and the majority (58.1%) were female. Figure 7 shows the age and gender distribution of the urban/rural sample versus the Wabamun and area population from the 2001 Census. Figure 8 shows the distribution for participants from the Paul First Nation compared to 2003 mid-year population of the Paul First Nation.

Figure 7: Age and Gender Distribution – Urban/Rural Participants

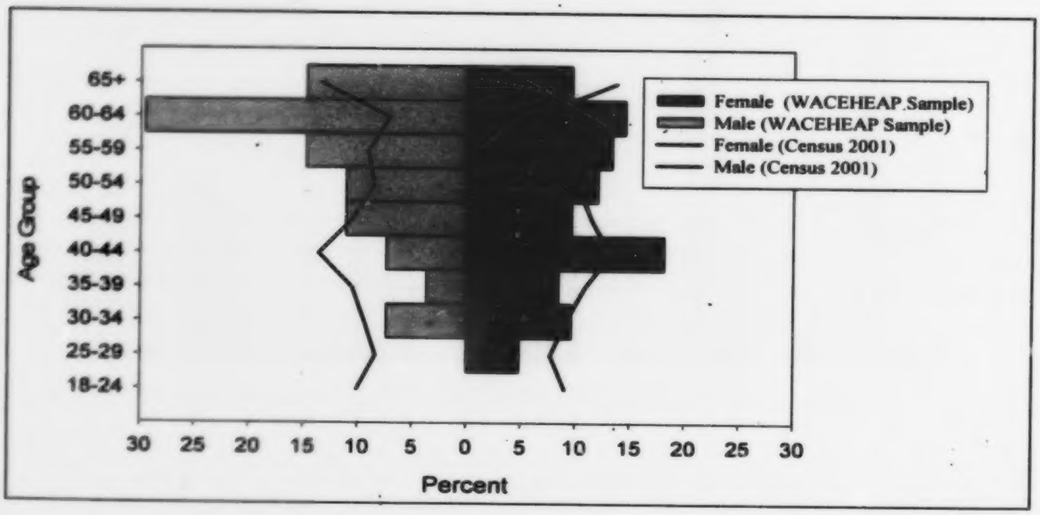
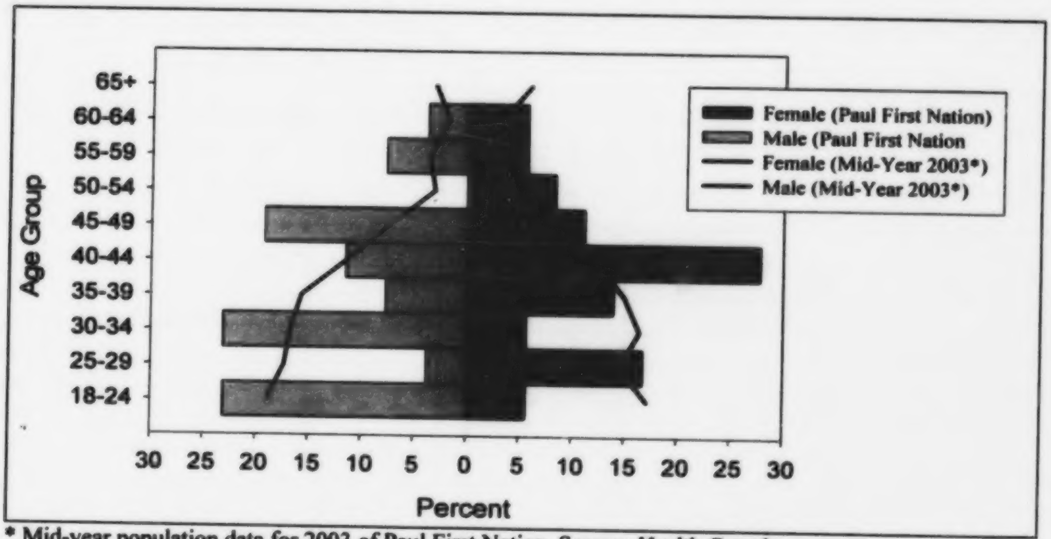


Figure 8: Age and Gender Distribution – Paul First Nation Participants

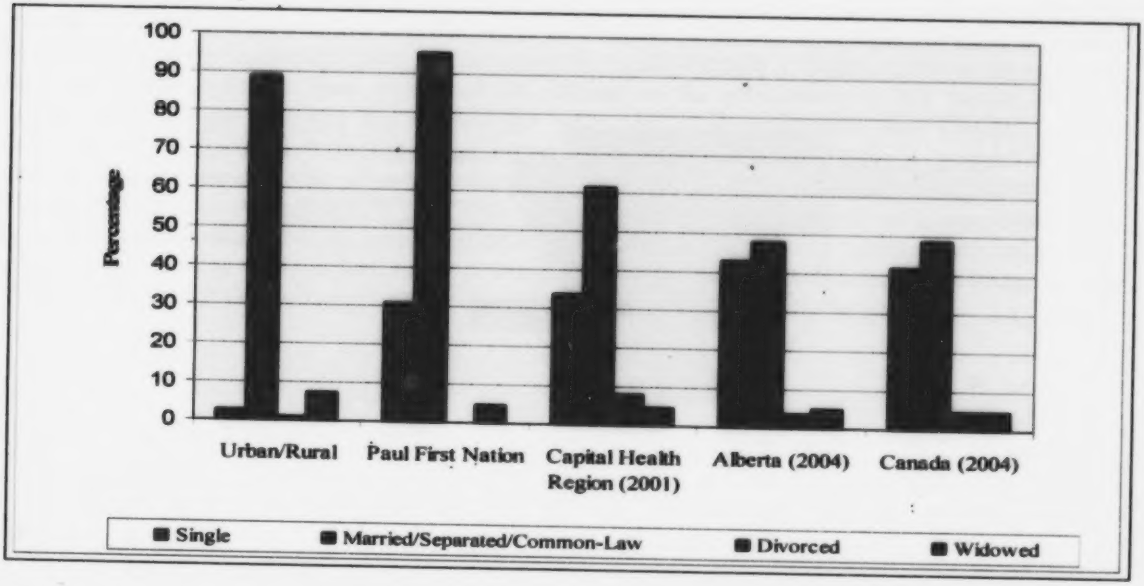


* Mid-year population data for 2003 of Paul First Nation. Source: Health Canada

6.3 Marital Status

Participants in the program were asked about their marital status and were compared to three other geographical groupings, Capital Health Authority, the Province of Alberta and Canada[13] to demonstrate the distribution of the sample. In order to conduct this comparison, the subcategory of married includes individuals who indicated separated and common-law. This grouping was defined by Statistics Canada. As Figure 9 demonstrates, both sample groups are similar in distribution to the three comparative geographical groupings.

Figure 9: Marital Status

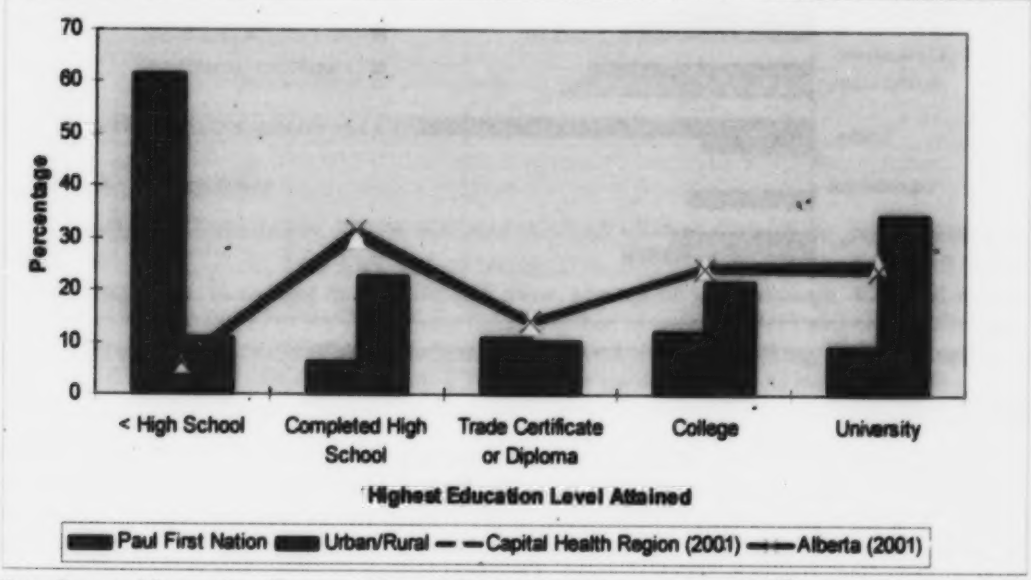


6.4 Education

Figure 10 compares the levels of education of the two subgroups in five education categories. Similar to marital status, education levels of the samples were compared against the population living in the Capital Health Region and the Province of Alberta in 2001.[14] As the graph describes, the urban/rural sample follows a similar distribution pattern when compared to the Capital Health Region and provincial data. The participants from Paul First Nation demonstrate a different distribution pattern with a high percentage not completing high school.

The average number of years of education reported by the urban/rural sample was 14.8 years (N=120, SD=2.7), whereas for participants from the Paul First Nation the average years of education was 12.2 (N=71, SD=2.5). Over 65% of urban/rural participants have completed at least one year of postsecondary education including training for a trade certificate or diploma. Participants from Paul First Nation however only indicated that 32.3% have gone on to complete trade certification or post secondary education.

Figure 10: Education Level



Note: Reported figures for Alberta and Capital Health Region from Census 2001.[15]

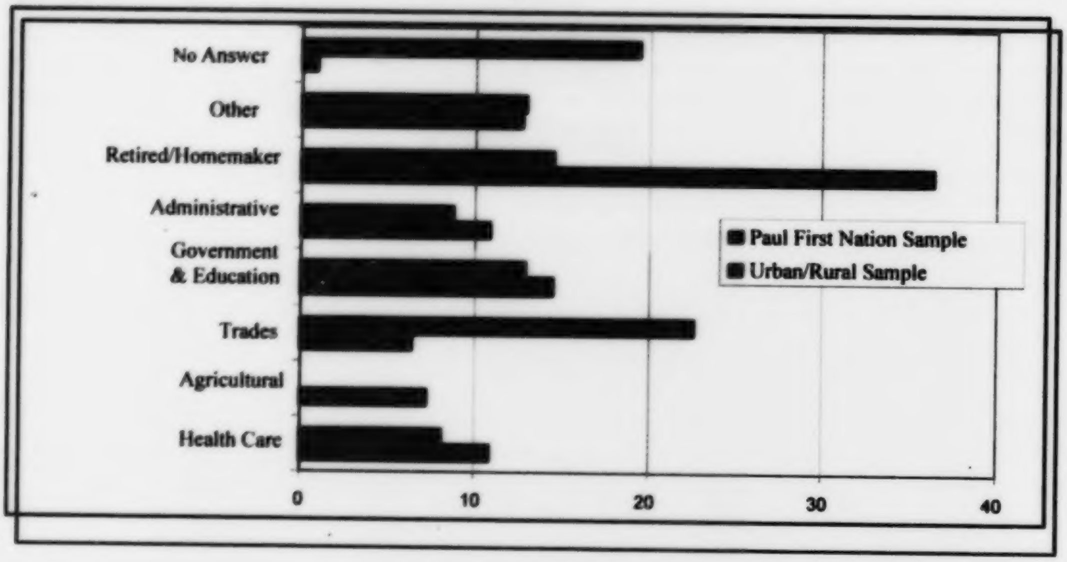
6.5 Language

English was indicated as the native or first learned language of 88.3% of the urban/rural sample. In the 2001 Census, 78.8% of the inhabitants from the Capital Health Region indicated English as their mother tongue.[16] While the highest portion of members of the Paul First Nation indicated English (28.2%) was the first language learned, the remaining members indicated three other languages may have been learned initially. These languages are Cree (19.7%), Sioux (11.3%) and Stoney (36.6%).

6.6 Occupation

Figure 11 shows the distribution of the participant's occupations in categories used by Statistics Canada. In the urban/rural sample, the largest proportion (36%) of the sample were either homemakers or retired versus in the Paul First Nation sample the largest portion (22%) indicated occupations in trades, transportation or equipment operations. It is important to note however that almost one fifth of the Paul First Nation Sample (19.4%) did not indicate an occupation at the time of the survey.

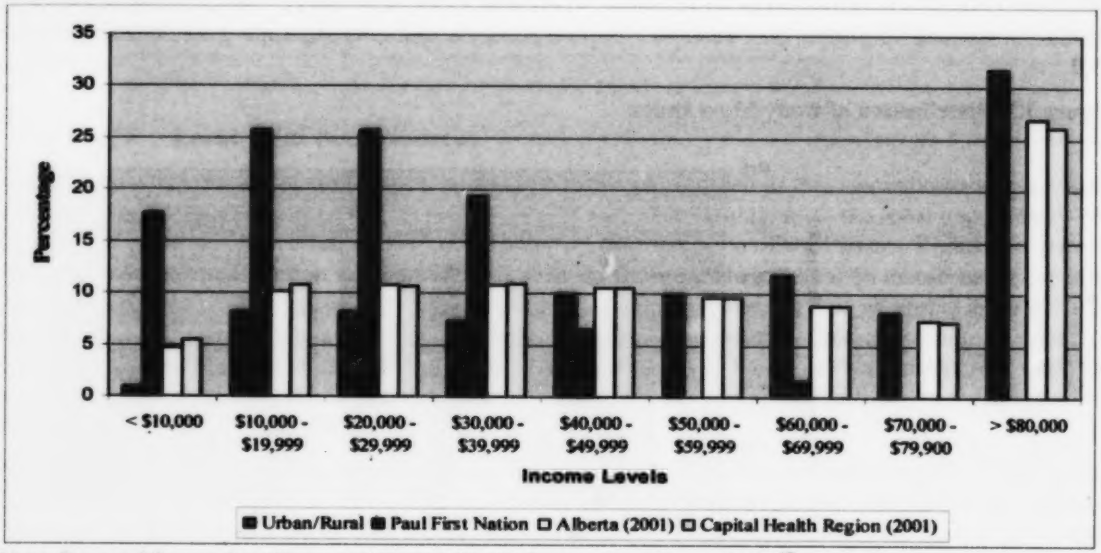
Figure 11: Distribution by Occupation in Samples



6.7 Income

In Figure 12, the income of the two subgroups were compared to income levels in the Capital Health Region and Alberta. For the urban/rural sample, the distribution of income follows a similar pattern as to that reported in the comparison data from the Capital Health Region and Province of Alberta. Over half of the urban/rural sample (51.8%) reported a household income of $60,000 or more. In the Paul First Nation Sample, 91.9% reported a household income of $39,999 or less.

Figure 12: Distribution of Household Income



Note: Reported figures for Alberta and Capital Health Region from Census 2001.[17]

6.8 Smoking

Of the urban/rural respondents, 43.6% indicated they had smoked as much as one cigarette a day for as long as one year. For the Paul First Nation respondents, 74.2% indicated they had smoked as much as one cigarette a day for as long as one year. Of those who are or were smokers, 40.7% of the urban/rural participants versus 78.0% of the Paul First Nation smoked between one (1) and thirty (30) cigarettes per day. In August 2005, Health Canada indicated the lowest national smoking rate in Canadian history at 20%, which was mirrored in Alberta with a 20% current smoker rate.[18] At the time of the project, 10.9% of urban/rural participants currently smoke, whereas 64.5% of the Paul First Nation participants are current smokers.

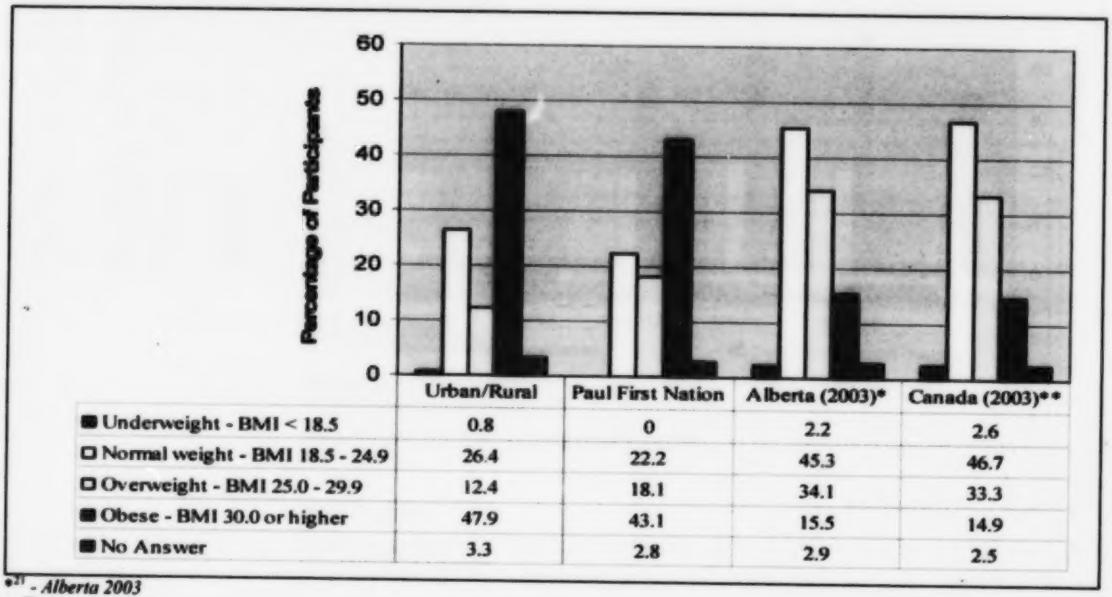
The participants were asked about their exposure to second hand smoke on a daily basis. A high percentage of respondents (78.2%) from the urban/rural sample versus 37.1% from the Paul First Nation indicated no exposure to second hand smoke. For those exposed daily to second hand smoke, the urban/rural sample indicated an average of 34.5 minutes of exposure, whereas Paul First Nation respondents indicated 133 minutes on average.

6.9 Body Mass Index

Body mass index (BMI) was calculated from the height and weight provided by each respondent. The BMI is considered a valid measure of obesity because it correlates well with skin fold and body density measures, and has been adopted in the *Canadian Guidelines for Healthy Weights.*[19] A BMI of less than 20 indicates that the individual is underweight for their height, and there may be some associated health problems. A BMI between 20 and 24 is considered a healthy range. A BMI of between 25 and 27 indicates that the individual is slightly overweight, which may lead to health problems for some people, while a BMI over 27 indicates an increased risk of health problems associated with weight.[20]

Figure 13 show the distribution of the BMI for both the urban/rural and Paul First Nation subgroup as compared to reported BMI's for the Province of Alberta and Canada. For both subgroups the percentage of respondents reporting a BMI of 25.0 or higher was over 60% (Urban/Rural – 60.3% and Paul First Nation 61.2%). These numbers are significantly higher than those collected by the Canadian Community Health Survey in 2003 where 49.6% and 48.2% of respondents in this survey reported a BMI higher than 25.0.

Figure 13: Distribution of Body Mass Index



	Urban/Rural	Paul First Nation	Alberta (2003)*	Canada (2003)**
■ Underweight - BMI < 18.5	0.8	0	2.2	2.6
☐ Normal weight - BMI 18.5 - 24.9	26.4	22.2	45.3	46.7
☐ Overweight - BMI 25.0 - 29.9	12.4	18.1	34.1	33.3
■ Obese - BMI 30.0 or higher	47.9	43.1	15.5	14.9
■ No Answer	3.3	2.8	2.9	2.5

*[21] - *Alberta 2003*
**[22] - *Canada 2003*

6.10 Nutritional Intake

Participants were asked about their usual dietary habits and their responses are summarized in Table 4. As is demonstrated in reported responses, neither subgroup is consuming the recommended servings of each food group especially in regards to grain products. Participants from the Paul First Nation consuming far lower portions of the recommended servings of the different food groups.

Table 4: Summary of Nutritional Intake

Recommended Servings (*as described in Canada's Food Guide to Healthy Eating)*	**% of Urban/Rural** (N = 110)	**% of Paul First Nation** (N = 62)	**% of Canadians** (2003)
5 or more servings of fruits and vegetables (per day)	72.7%	36.6%	39.0%
2 or more servings of milk or dairy products (per day)	52.3%	12.3%	**No data available**
5 or more servings of grain products (per day)	12.0%	12.9%	**No data available**
2 or more servings of meat or meat alternatives (per day)	67.3%	48.4%	**No data available**

For both samples, the respondents indicated they consumed on average at least one (1) serving or more of sweets or non-nutritious foods. Participants from both samples also reported similar findings for coffee and tea consumption which on average two cups per day, and less than one drink per day of cola or alcohol.

6.11 Local Wild Food Sources

The frequency of consumption of local wild food sources was recorded as this can indicate whether there are other sources of contaminants or pathways of exposure that are unique to the local population. The most significant difference between the two samples was consumption of wild game. Eighty two percent (82%) of the Paul First Nation respondents indicated consuming wild game, with moose being the most popular wild meat. Consumption of wild game for urban/rural respondents was measured at 33.6% with deer and moose equally popular. For fish, similar number of respondents reported consuming wild fish, Urban/Rural – 37.3%, Paul First Nation – 32%. Respondents from Paul First Nation reported whitefish was the most popular whereas for the urban/rural participants a diverse array of fish was indicated which includes whitefish, trout and pike.

Again both subgroups indicated similar consumption levels of wild berries, urban/rural – 78.2% versus Paul First Nation respondents – 82%. The consumption rates of local fruits and vegetables were different for both samples groups with the urban/rural participants reporting 94.5% and Paul First Nation participants indicating 61.4%.

6.12 Sources of Drinking Water

Data was collected on characteristics of household drinking water and personal drinking water habits as the source of drinking water could be an important route of exposure. The urban/rural sample was equally served by either municipal (47%) or well (50%) sources of drinking water. For the Paul First Nation, the source of drinking water for the majority of respondents was a well source (81%) with the remaining portion a combination of water hauled to a cistern, surface water or municipal water source (2%). Both samples indicated similar rates of usage of tap water as their drinking water source: urban/rural 68.2%, Paul First Nation 74.2%. When drinking water from the tap, 55% of the urban/rural sample indicated running the water for a period of time before filling their glass, whereas 75.5% of Paul First Nation performed this task prior to water consumption.

About one-third (36.7%) of urban/rural respondents indicated that they have a filter of some type that purifies the water, most of which contain activated carbon (e.g., Brita, Amway). Very few respondents from Paul First Nation (92.2%) use any type of point of use filter system. Bottled water usage is similar for both groups: 65.7% (urban/rural) versus 67.3% (Paul First Nation) with primary usage for both groups being for all drinking purposes or drinking when travelling.

6.13 Physical Activity Level

The physical activity section of the Health Habits and Diet Survey assessed participants' involvement in a variety of physical activities. Health Canada recommends at least 20-30 minutes of vigorous activity, or 60 minutes of light effort, every day, to maintain good health.[23] The mean time spent in physical activity in the urban/rural sample was 6.1 hours/week (53 minutes/day), indicating that many participants barely meet Health Canada's minimum requirements for physical activity. For the Paul First Nation respondents, the mean time spent in physical activity was lower with 4.2 hours/week (36 minutes/day). The proportion of participants following Health Canada's recommendations of one (1) hour of activity per day for the urban/rural sample was 33.6%, with a lower percentage of Paul First Nation respondents

12.9%. This low physical activity rate correlates with the large proportion of participants in both groups with a BMI higher than the healthy range.

6.14 Length of Residence

The length of residence of the participants in the program boundaries was determined from responses in the Demographic and Exposure Survey. Participants were asked to indicate their address at birth and provide their history of residence throughout their lifetime. For members of the urban/rural subgroup, the average length of residency within the program boundaries was 12.89 years (N=109, SD = 10.5). Participants from Paul First Nation have been residents in the area on average for 25.2 years (N=54, SD=18.4). The distribution of the samples is described in Table 5.

Table 5: Distribution of Length of Residency

Category	Urban/ Rural Sample N=109	Paul First Nation Sample N=54
Less than 5 years	38 (34.9%)	12 (22.2%)
6 – 10 Years	16 (14.7%)	4 (7.4%)
11 – 15 Years	20 (18.3%)	4 (7.4%)
16 – 25 Years	17 (15.6%)	9 (16.7%)
26 – 35 Years	17 (15.6%)	8 (14.8%)
36 – 45 Years	1 (0.9%)	9 (16.7%)
46 – 55 Years		5 (9.3%)
56 – 65 Years		3 (5.6%)

6.15 Meteorological Data

The wind diagrams in Figures 14 to 16 describes the percent of time the wind blows from various directions and speeds as measured at the three monitoring sites in the program area. As the wind diagrams show, the predominant wind direction is from the west with subtle variations between the three monitoring sites. These wind diagrams were calculated from readings from May to October 2004.

Figure 14: Wind Rose Diagram Showing Wind Characteristics at the Wagner Air Monitoring Station

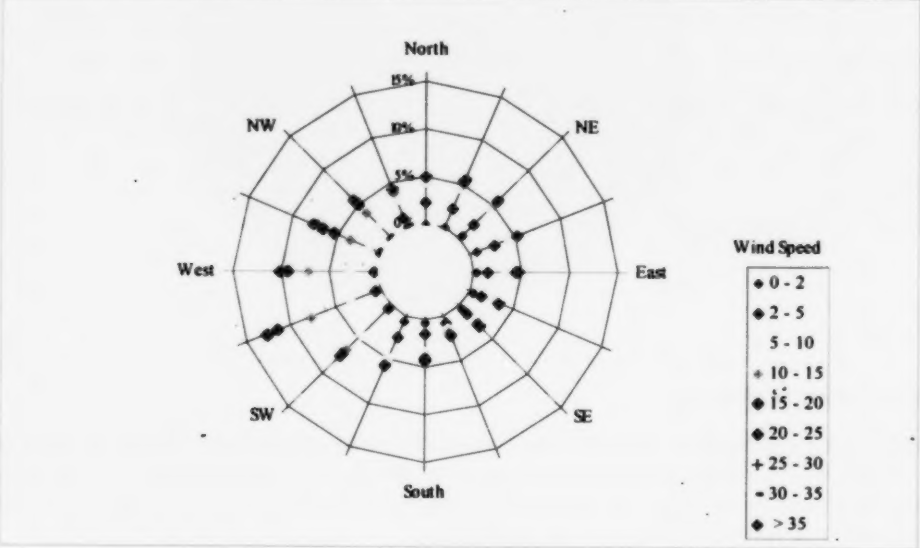


Figure 15: Wind Rose Diagram Showing Wind Characteristics at the Meadows Air Monitoring Station

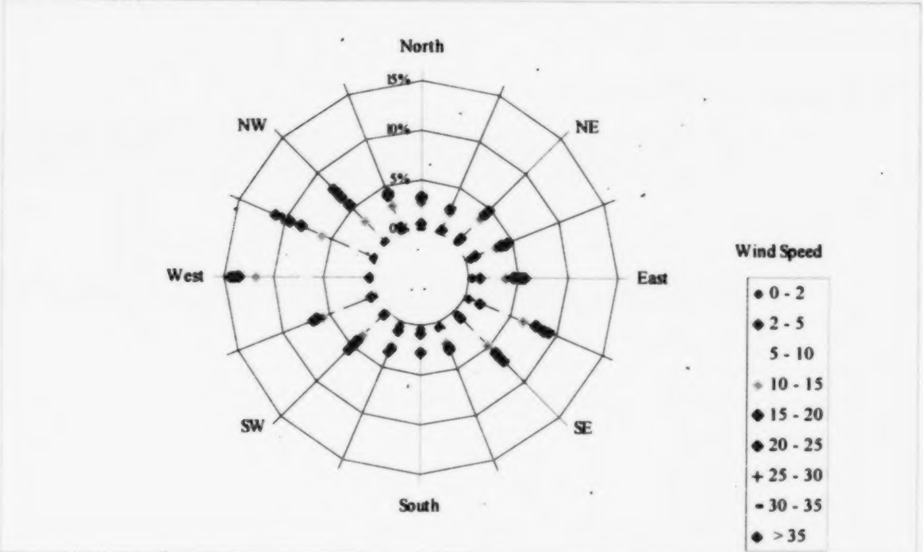
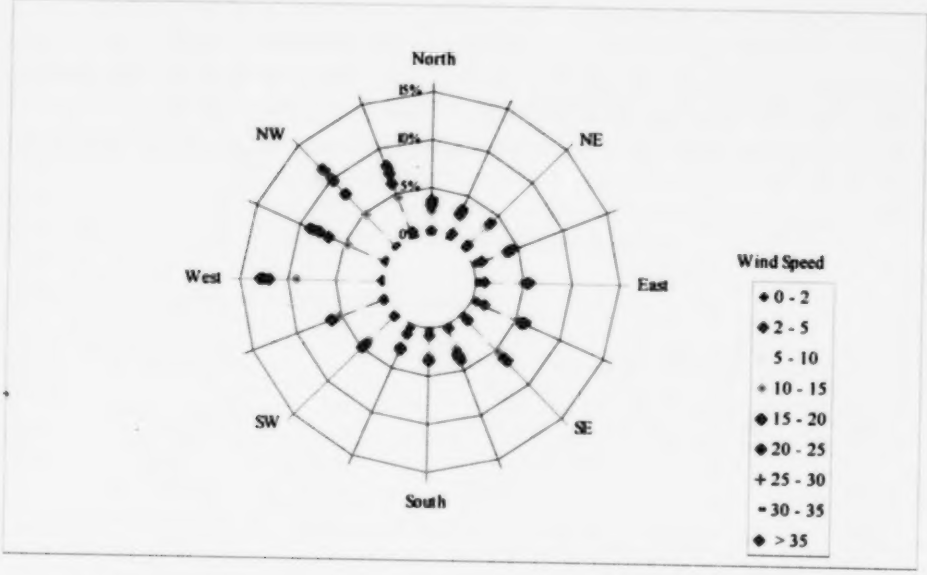


Figure 16: Wind Rose Diagram Showing Wind Characteristics at the Genesee Air Monitoring Station



6.16 Time Activity Diaries

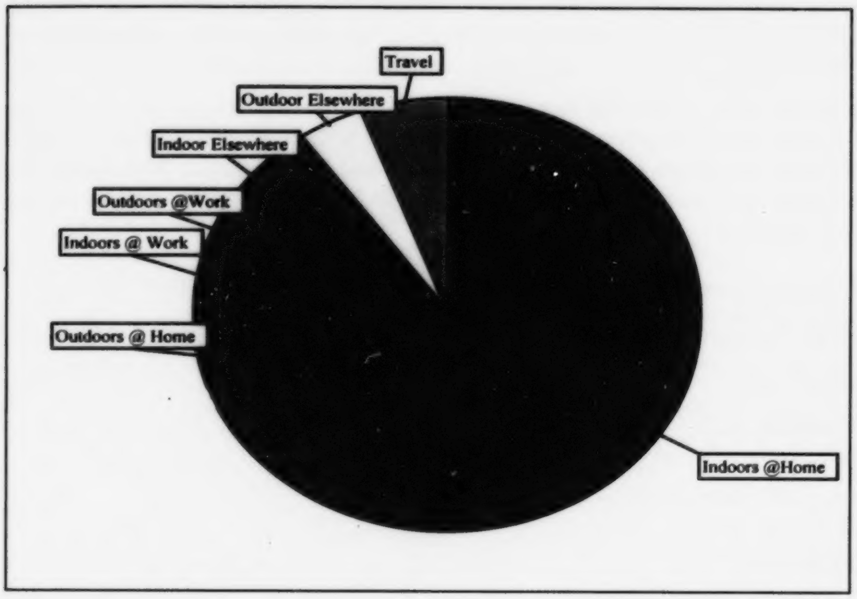
Participants were asked to record the time spent at various mutually exclusive locations for the duration of their participation. Table 6 shows that gender and job status are also a major determinant of the relative activity mix between home and work. The not employed category in this table refers to individuals who are unemployed, homemakers, retired or persons with disabilities.

Figure 17 represents how time was spent for all participants. There were trade-off relationships among the relative mixes of general activities across different individuals. The primary trade-off involved time spent indoor at home versus time spent in other indoor or outdoor activities; and independently time spent indoors at home versus time spent indoors at work.

Table 6: Activity Mix by Gender and Job Status

	Indoors at Home (proportion)	Indoors at Work (proportion)
Female		
Not employed	0.71	0.01
Part time Job	0.69	0.07
Full time Job	0.58	0.08
Male		
Not employed	0.65	0.00
Part time Job	0.62	0.03
Full time Job	0.52	0.13

Figure 17: Average Proportion of Time Spent in a Day by Participants



7.0 Air-Borne Contaminants

7.1 Passive Samplers

Passive air quality measurements were taken with four separate samplers, each deployed for a one-week period. Each participant carried samplers around their neck hanging in their breathing zone (Personal sample), had a sampler deployed inside their home (Indoor sample), and had a sampler deployed in the environment immediately outside their home (Outdoor sample). Table 7 shows the sampler types and the chemicals monitored by each sampler.

Table 7: Samplers and Chemical Concentrations Measured

Sampler	Chemical Concentrations Measured
NO_2	Nitrogen Dioxide
SO_2	Sulfur Dioxide
O_3	Ozone
Volatile Organic Compounds	Hexane
	3-methylhexane
	Benzene
	Heptane
	Toluene
	Octane
	Ethylbenzene
	m-, *p*-xylene
	o-xylene
	Nonane
	Decane
	Limonene
	N-butyl-benzene
	N-propyl-benzene

The Field Teams deployed 3,163 passive air monitors throughout the course of the program. Three of these monitors were replacements for ones that had been damaged or lost by the participant. From fourteen (14) of the passive air monitors, data could not be quantified as the monitors had become damaged or were not reported lost by participants so replacements could be issued. Table 8 shows how the remaining 3,146 passive monitors were distributed.

Table 8: Distribution of Passive Air Monitors

Number by Location	Number by Type
767 Personal	190 NO_2
	192 SO_2
	193 O_3
	192 VOCs
772 Indoor	193 NO_2
	193 SO_2
	193 O_3
	193 VOCs
763 Outdoor	188 NO_2
	191 SO_2
	192 O_3
	192 VOCs
772 Blank	193 NO_2
	193 SO_2
	193 O_3
	193 VOCs
72 Ambient	18 NO_2
	18 SO_2
	18 O_3
	18 VOCs
Total	**3,146**

Calculation of the concentrations of each chemical from the amount of material detected on each sampler filter involved formulae relating sampling rates to concentration levels. In addition, a time correction was applied to correct for the precise amount of time (in minutes) that the samplers were exposed to air. A correction for blank levels (levels measured on unexposed sampler filters) was also applied. This correction itself involved an examination of the variability of the blank values over the course of the program, and for some chemicals resulted in a complex time dependent correction.

In the sections that follow, three graphs are presented to describe the program results for each chemical.

The first graph shows the distribution of all measures taken throughout the Wabamun program period for each of the sample(r) types: personal, indoor, and outdoor. The graph plots the calculated average concentration in the air to which the sampler was exposed plotted against the percentile of this exposure level in the particular sample type across all samples collected. The median exposure level is located at the point where a vertical line drawn from the 50th percentile mark on the horizontal axis intersects with the curve. The concentration level at that point is read from the vertical axis by drawing a horizontal line from that point on the curve to the vertical axis. The vertical axis is presented as a logarithmic scale that reflects the general finding of positive skew in distributions of chemicals in air. If the line deviates from a straight line and especially if the curvature is marked at either end (usually the end indicating higher exposure levels), this indicates a skewed distribution of exposure to that chemical more marked than the log normal distribution. The degree of slope in the linear section of the curve is related to the overall variability of the sample such that steeper slopes indicate more variable distributions. Curves that do not appear to start at percentile 0 indicate that a proportion of cases fell below the blank level for the sampler for that chemical. The proportion of samples for which this is true is determined by noting the percentile level at which the curve begins.

The second graph represents a line of best fit derived by locally weighted regression methods to show the temporal trend in the sampled concentrations for each sample type. The lines appear smooth, but they typically represent a very weak relationship between season and concentration. To illustrate that this relationship is weak, the individual concentrations are plotted on this graph as points. As well, the duration of the sampling (approximately 6 months) restricts the ability to fully determine the shape of any yearly cycle that might be present in the data.

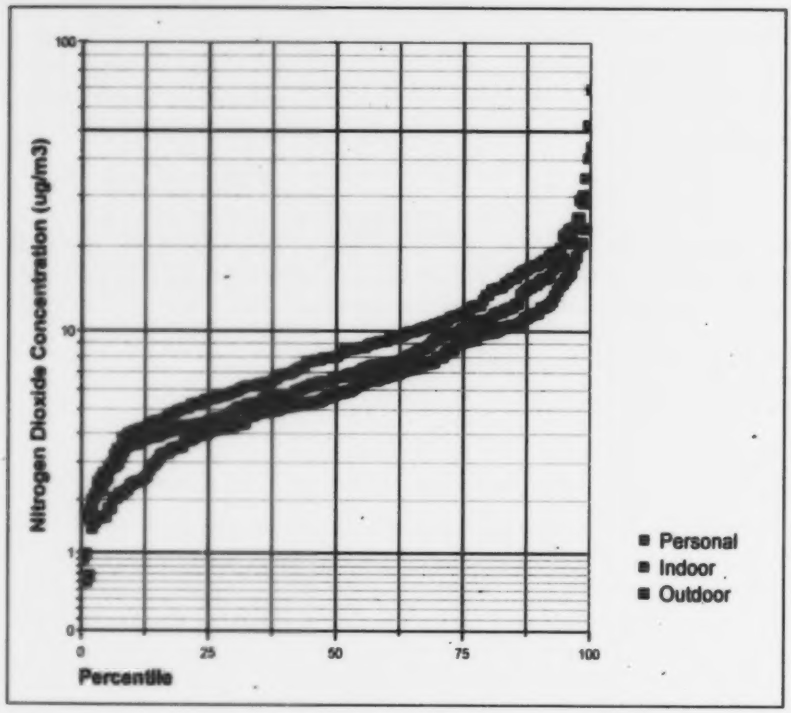
The third graph was designed to give an indication of the degree of relationship between levels of personal exposure and levels of indoor and outdoor concentrations respectively. It is created as follows: first, personal exposure values are ranked from highest to lowest; second, a graph is created which orders the data from highest to lowest (where the concentration is given on the vertical axis, and the order values for each participant are presented along the horizontal axis); third, the values for outdoor and indoor concentrations are plotted at the horizontal point in the graph at which the point indicating the personal concentration for that participant had previously been plotted; fourth, a locally weighted regression line is produced to help visualize the association between personal exposure and indoor exposure and between personal exposure and outdoor exposure. For strong relationships, the interpolated lines for the associated sampler sites will mimic the general downward trend of the line for personal exposure (and at the same time the points will cluster closely around this line). The stronger the relationship, the closer the curves will be to being parallel to each other. Weak or non-existent relationships will be characterized by interpolated lines that are parallel or close to parallel to the horizontal axis. In general, even strong apparent relationships had only moderate correlations (0.4-0.5) between personal exposure and either indoor or outdoor exposure.

Nitrogen Dioxide (NO_2)

In Alberta, nitrogen dioxide emissions are produced by vehicles, industry sources (oil and gas) and power plants. More localized sources of exposure are natural gas combustion, heating fuel consumption and forest fires. The method detection limit (MDL) for the NO_2 sampler is 2.1 $\mu g/m^3$ with all samplers except for a low percentage of indoor and outdoor (<2%) above the detection limit. While the imprecision associated with individual outdoor samples increases dramatically when measures fall below the detection limit, the data provides a prediction of overall community exposure.

Figure 18 shows the cumulative distribution of NO_2 concentrations for the three types of samplers (personal, indoor, and outdoor). Concentrations measured on the personal samplers were slightly higher than either the outdoor or indoor samplers, but as shown in the graph the differences were not significantly higher.

Figure 18: Distribution of Nitrogen Dioxide



The median and 95th percentile NO_2 levels ($\mu g/m^3$) for the different locations are summarized and compared to guidelines and levels in other CEHEAP communities in Table 9. In addition, the relative levels of NO_2 at the locations are compared by the ratios of personal to indoor (P/I), personal to outdoor (P/O), and indoor to outdoor (I/O). In this program, the lowest levels of NO_2 were detected at all three locations compared to other CEHEAP communities. The indoor and outdoor levels of NO_2 were also significantly below guideline levels and in the case of the outdoor sampler half the value of relevant studies.

Table 9: Comparison of NO_2 Levels in µg/m^3 with Guidelines and Other Studies[24,25,26]

Parameter	Personal	Indoor	Outdoor	Ambient Station	P/I ratio	P/O ratio	I/O ratio
Wabamun Median	8.1	6.8	5.8	3.02	1.2	1.4	1.2
Wabamun 95th	23.0	21.0	15.9	4.62	1.1	1.4	1.3
Fort Saskatchewan Median	13.7	10.0	10.4	N/A	1.4	1.6	1.2
Fort Saskatchewan 95th	30.6	27.2	30.9	N/A	1.1	1.0	0.9
Grande Prairie Median	11.6	9.1	4.7	N/A	1.3	2.5	2.0
Grande Prairie 95th	30.2	25.8	16.5	N/A	1.2	1.8	1.5
Fort McMurray Median	15.9	8.6	9.5	10.8	1.9	1.7	0.90
Fort McMurray 95th	53.2	30.0	38.5	36.0	1.8	1.4	0.78
Lethbridge Median	17.7	9.8	13.8	N/A	1.8	1.3	0.71
Lethbridge 95th	41.6	30.3	42.8	N/A	1.4	1.0	0.71
Relevant Studies	N/A	6[i]	12[i]	N/A	N/A	0.65[i]	
Guideline/Reference Level	N/A	480(hour)[iii]	200 (24 hour)[ii]	400 (1 hour)[ii]	N/A	N/A	

i: Hagenbjork-Gustafsson et al., 1996.
ii: Alberta's Ambient Air Quality Objectives, 2005
iii: Health Canada, 1989.

Figure 19 shows smoothed curves (produced by locally weighted regression) to represent the temporal trend in NO_2 concentrations. As can be seen in the graph as outdoor concentrations increase into later summer and early fall, personal and indoor concentrations mirror this increase.

Figure 19: Temporal Trend in Nitrogen Dioxide Concentration

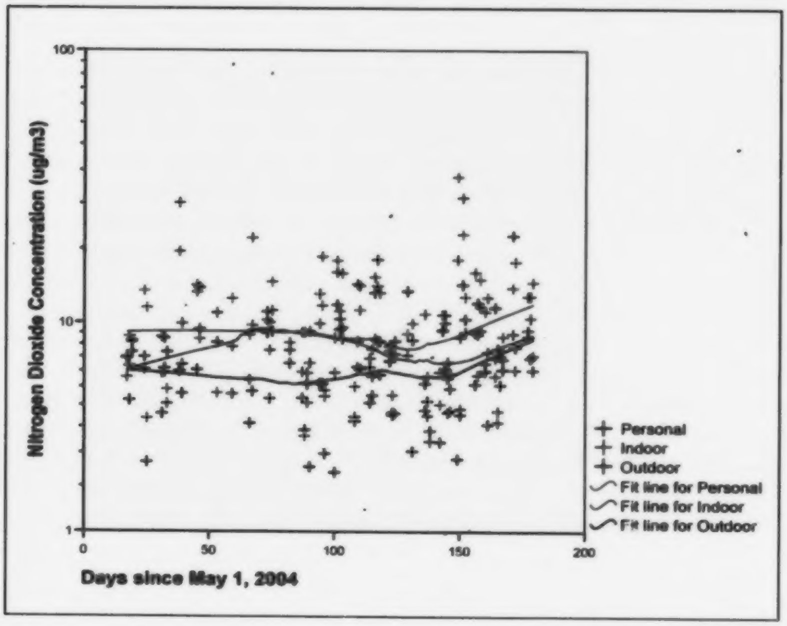
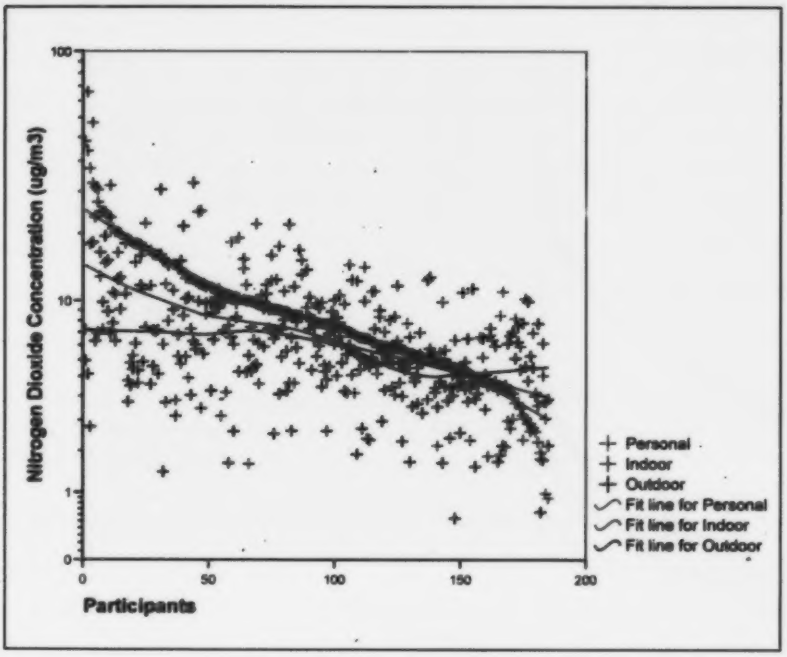


Figure 20 shows the relationship between the NO_2 concentrations monitored personally, indoors and outdoors. The graph shows the ordered personal exposure levels for each subject in the program, and their corresponding levels of indoor and outdoor concentration levels. A locally weighted regression curve has been added for indoor and outdoor concentration levels to give an indication of the strength of the association between personal levels and indoor and outdoor levels respectively. A horizontal line would show no relationship, while positive associations would be shown by sloped lines (and particularly by the relative degree of scatter of the individual points around those lines). This graph shows a moderate relationship between measures of indoor and personal concentrations with minor influence from outdoor concentrations.

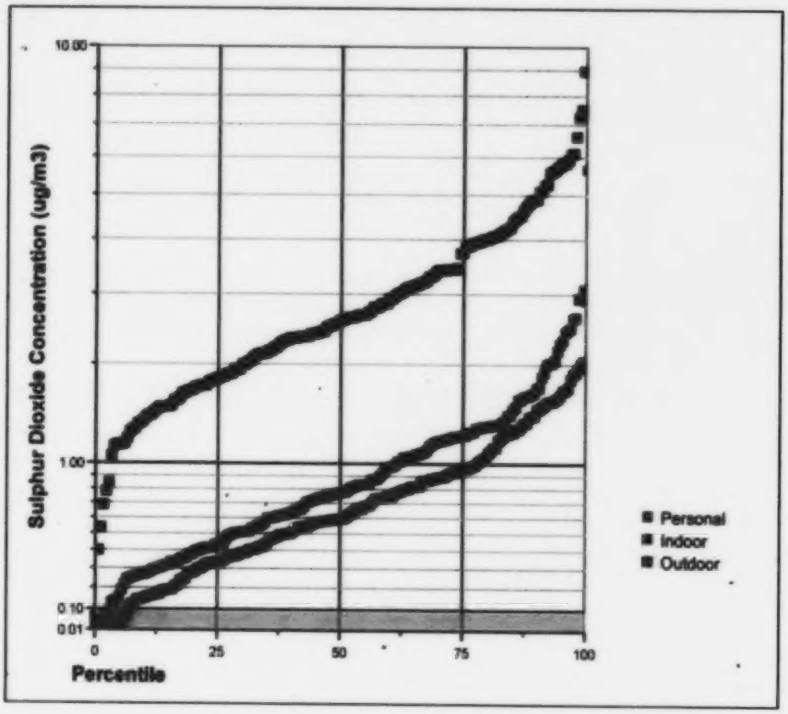
Figure 20: Relationship between Exposures to Nitrogen Dioxide by Sampler Site



Sulfur Dioxide (SO_2)

Sulfur dioxide is formed during the processing and combustion of fossil fuels containing sulfur. Industries involved in producing SO_2 include gas plant flares, oil refineries, pulp and paper mills, fertilizers plants, coal-fired power plants, and power generating stations. Figure 21 shows the cumulative distribution of SO_2 concentrations for the three types of samplers (personal, indoor, and outdoor). The MDL of SO_2 is 1.1 µg/m^3, with a significant portion of the personal (48.4%) and indoor (62.3%) below this limit. The majority of outdoor samplers (98.3%) were above the MDL. As is shown in Figure 21, outdoor concentrations of SO_2 were highest in outdoor air and lowest in home indoor environments. The median outdoor concentrations are approximately triple the personal concentrations and quadruple the indoor concentrations.

Figure 21: Distribution of Sulfur Dioxide



The median and 95th percentile SO_2 levels (µg/m^3) for the different locations are summarized in Table 10 and compared to guidelines and levels in other CEHEAP communities. The levels of SO_2 measured in the Wabamun area were much lower than guidelines and similar to other communities who have participated in this program.

Table 10: Comparison of SO_2 Levels in µg/m³ with Guidelines and Other Studies[27,28]

Parameter	Personal	Indoor	Outdoor	Ambient Station	P/I ratio	P/O ratio	I/O ratio
Wabamun Median	0.8	0.6	2.6	4.24	1.3	0.3	0.2
Wabamun 95th	2.4	1.7	5.8	6.55	1.4	0.4	0.4
Fort Saskatchewan Median	0.70	0.34	2.30	N/A	2.2	0.30	0.14
Fort Saskatchewan 95th	2.27	1.08	4.94	N/A	1.89	0.42	0.22
Grande Prairie Median	0.37	0.017	0.86	N/A	2.14	0.42	0.20
Grande Prairie 95th	1.83	1.18	2.23	N/A	1.54	0.82	0.53
Fort McMurray Median	0.87	0.41	1.60	2.00	2.1	0.53	0.25
Fort McMurray 95th	5.60	4.10	8.00	6.50	1.4	0.70	0.52
Lethbridge Median	0.21	0.16	1.10	N/A	1.3	0.19	0.15
Lethbridge 95th	3.10	2.90	5.20	N/A	1.1	0.59	0.56
Relevant Studies	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Guideline/Reference Level	N/A	1000 (5 min)[i]	450 (one hour)[ii] 150 (24 hour)[ii]	450 (one hour)[ii] 150 (24 hour)[ii]	N/A	N/A	N/A

i: Health Canada, 1989.
ii: Alberta's Ambient Air Quality Objectives, 2005

Figure 22 shows smoothed curves (produced by locally weighted regression) to represent the temporal trend in SO_2 concentrations. Changes in outdoor concentrations are reflected in changes in indoor and personal concentrations.

Figure 22: Temporal Trend in Sulfur Dioxide Concentration

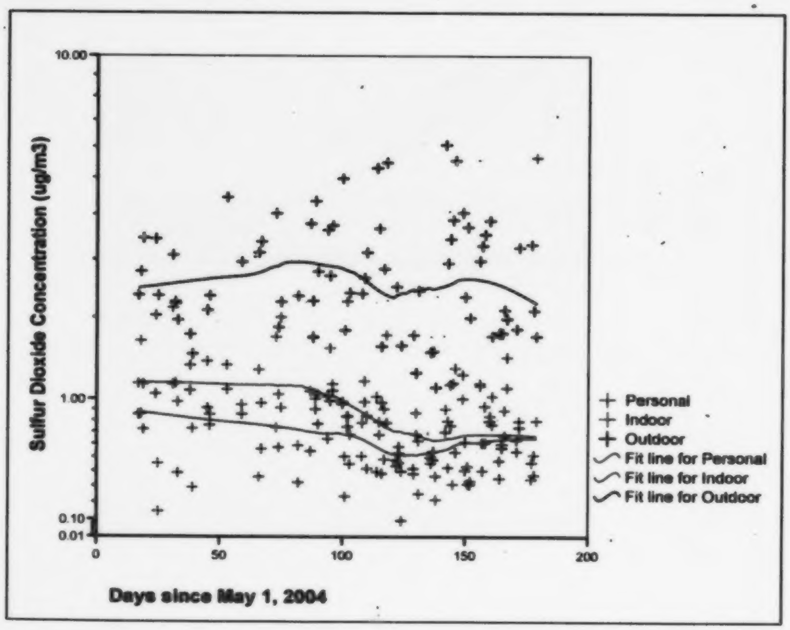
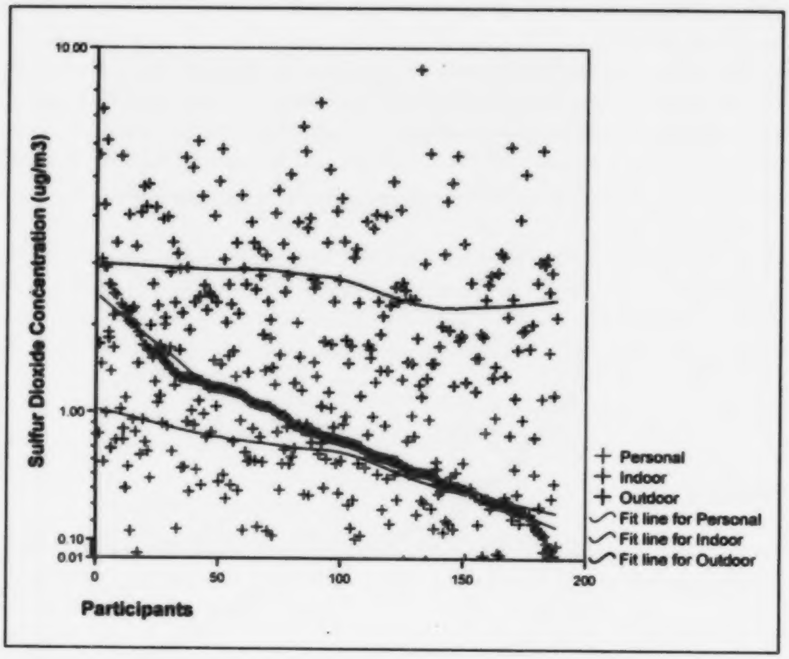


Figure 23 shows the relationship between the concentrations monitored personally, indoors and outdoors. This graph shows a moderate relationship between personal and indoor concentrations but a weaker relationship between personal and outdoor concentrations.

Figure 23: Relationship between Exposures to Sulfur Dioxide by Sampler Site

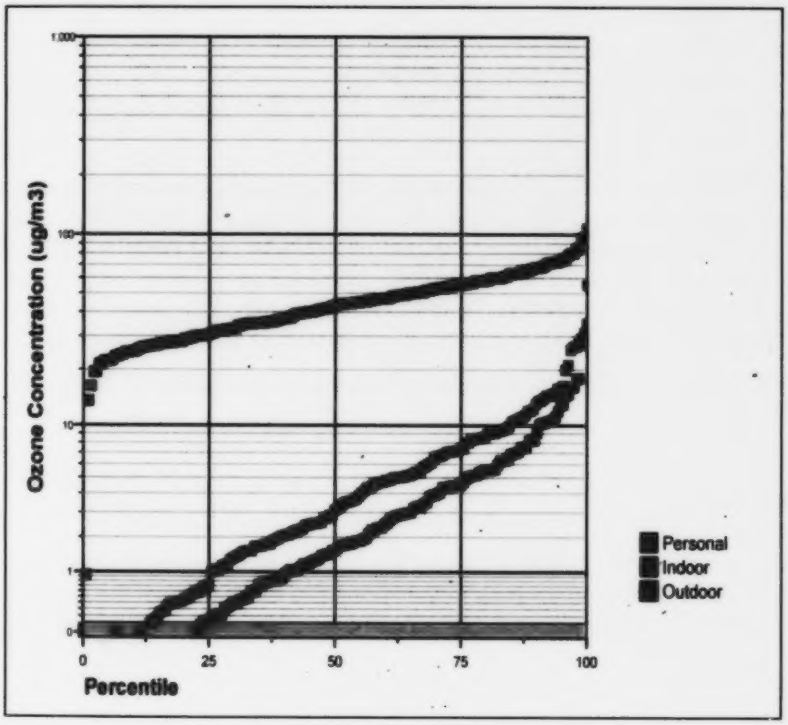


Ozone

Ozone is a naturally occurring gas, generated in the higher layers of the atmosphere but is also produced indirectly by industrial activities. Ground level ozone is generated by a photochemical reaction of oxides of nitrogen (NO_x) and volatile organic compounds (VOCs). The MDL for the ozone samplers is 0.82 $\mu g/m^3$ with all samplers (personal, indoor and outdoor) detecting ozone above this minimal level.

Figure 24 shows the cumulative distribution of ozone concentrations for the three types of samplers. The median outdoor concentrations were over one order of magnitude higher than the personal and indoor concentrations. Scientific research has determined outdoor and ambient levels of ozone exposure are commonly higher than those detected at the personal level.[29] An explanation for this difference could be a reflection as to how ozone is destroyed as it chemically reacts with other components in the air. These findings reveal the inherent inaccuracy of using ambient concentration levels as a reflection of personal exposure.

Figure 24: Distribution of Ozone



The median and 95th percentile O_3 levels (µg/m^3) for the different locations are summarized in Table 11 and compared to guidelines and levels in other communities. Based on the median, the levels of ozone determined in the Wabamun program area are the lowest in all the CEHEAP studies. Also, the concentration of each type of sampler does not vary significantly at 95th percentile compared to other previously monitored communities.

Table 11: Comparison of O_3 Levels in µg/m^3 with Guidelines and Other Studies[30,31,32,33]

Parameter	Personal	Indoor	Outdoor	Ambient Station	P/I ratio	P/O ratio	I/O ratio
Wabamun Median	3.2	1.6	43.9	60.6	2.0	0.07	0.04
Wabamun 95th	18.4	13.6	75.7	82.5	1.4	0.24	0.18
Fort Saskatchewan Median	6.1	4.0	47.4	N/A	1.5	0.1	0.1
Fort Saskatchewan 95th	21.0	19.8	69.7	N/A	1.1	0.3	0.3
Grande Prairie Median	4.7	2.2	51.2	N/A	2.15	0.09	0.04
Grande Prairie 95th	16.5	13.6	94.3	N/A	1.21	0.17	0.14
Fort McMurray Median	3.3	2.4	39	50	1.3	0.08	0.06
Fort McMurray 95th	18	15	91	100	1.2	0.20	0.16
Lethbridge Median	4.9	2.4	57	N/A	2.0	0.09	0.04
Lethbridge 95th	20	11	140	N/A	1.8	0.15	0.08
Relevant Studies	16 (summer)[i] 2.6 (winter)[i]	14 (summer)[i] 3.1 (winter)[i]	37 (summer)[i] 30 (winter)[i]	N/A	1.2 (summer)[i] 0.81 (winter)[i]	0.43 (summer)[i] 0.08 (winter)[i]	0.41[ii] 0.37 (summer)[i] 0.10 (winter)[i]
Guideline/Reference Level	N/A	240 (hour)[iii]	160 (one hour)[v] 125 (8 hour)[iv]	160 (hour)[v] 125 (8 hour)[iv]	N/A	N/A	N/A

i Lui, et al., 1995.

ii Bernard et al., 1999.

iii Health Canada, 1989.

iv Canada-wide standard, 2010

v: Alberta's Ambient Air Quality Objectives, 2005

Figure 25 shows smoothed curves (produced by locally weighted regression) to represent the temporal trend in ozone exposures. Outdoor concentration levels peak in the spring and decrease over the summer into the fall. This general trend is reflected in the personal and indoor concentrations with indoor levels appearing to peak in the summer.

Figure 25: Temporal Trend in Ozone Concentration

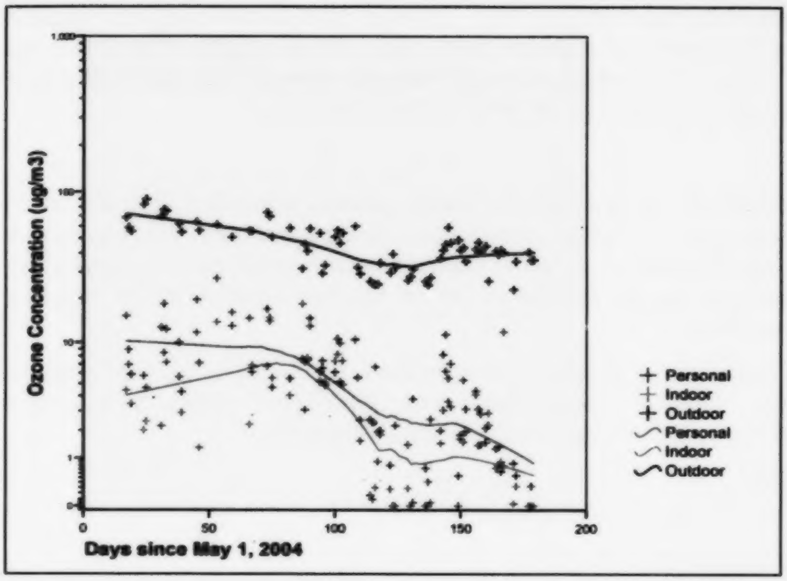
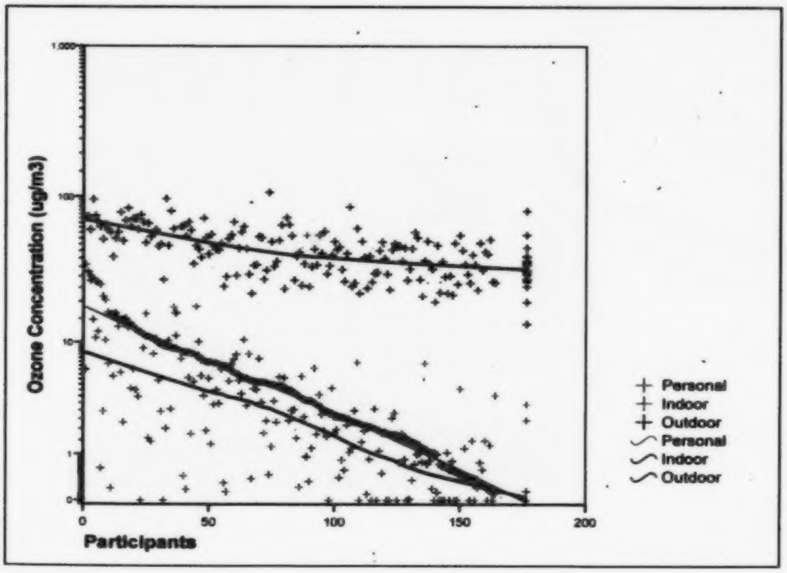


Figure 26 shows a strong relationship between personal and indoor exposure concentrations such that high levels of personal exposure are consistently associated with higher levels of indoor exposure concentrations. The relationship between outdoor exposures and personal exposures is considerably weaker, but positive nonetheless. The relative levels of the three exposures is strongly suggestive of a model of ozone diffusion which moves from outdoors to indoors and then to the person, who also moves outdoors often enough to raise personal exposure levels above the indoor concentration levels.

Figure 26: Relationship between Exposures to Ozone by Sampler Site



Volatile Organic Compounds

The analyses of the volatile organic compounds (VOCs) detailed in the following pages share several general features: 1) there were generally many measurements that were below detection limits especially for outdoor monitors (see Table 2); 2) personal exposure levels were generally higher than indoor and outdoor levels; and 3) the strongest relationships occurred between personal and indoor levels of concentration, suggesting indoor sources of exposure for most of these chemicals.

Hexane

Hexane is both naturally and synthetically produced and has a mild, gasoline type odour. Found in small amounts in both crude oil and natural gas, it also used in industrial extraction processes. It is also used as a cleaning agent for textiles, furniture and leather so can be expected to be found in indoor environments. The MDL for hexane is 2.2 µg/m^3 and was not detected in 50% of personal monitors, 62.2% of indoor monitors, and 95.8% of outdoor monitors.

Figure 27 shows the cumulative distribution of hexane concentrations for the three types of samplers (personal, indoor, and outdoor). Personal concentrations were significantly higher than outdoor concentrations at the median, and continue to increase an indoor concentration rises.

Figure 27: Distribution of Hexane

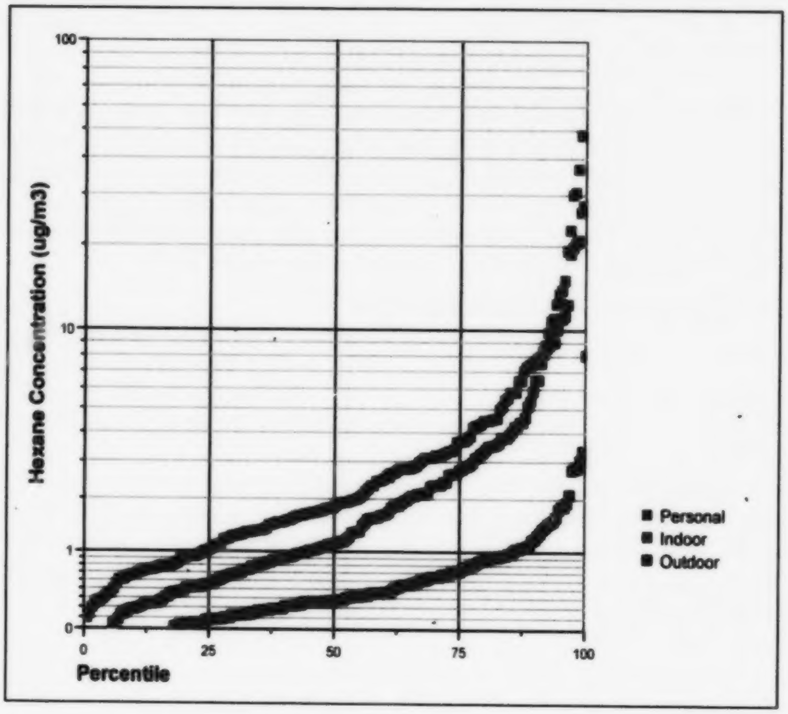


Figure 28 shows the temporal trend in hexane concentrations during the program period. There is little scientific evidence about a seasonal pattern for hexane. These results show hexane remains relatively constant throughout the sampling period.

Figure 28: Temporal Trend in Hexane Concentration

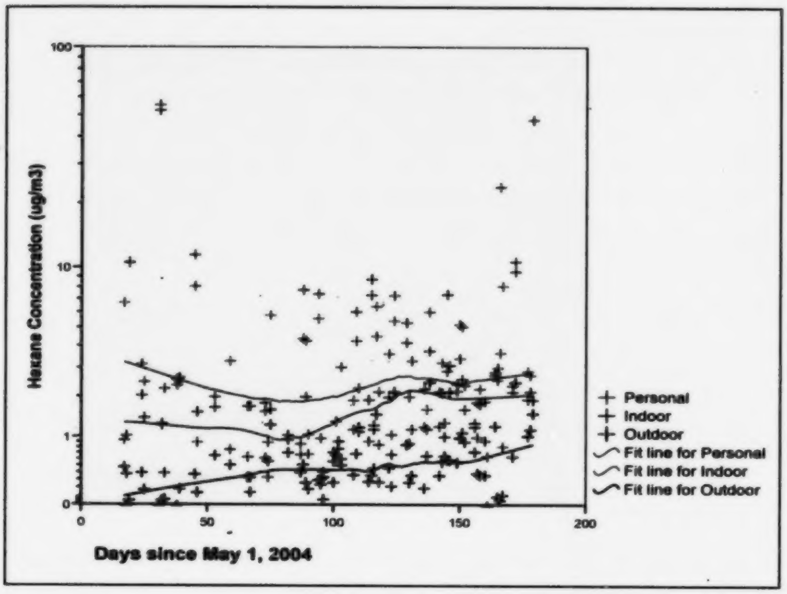
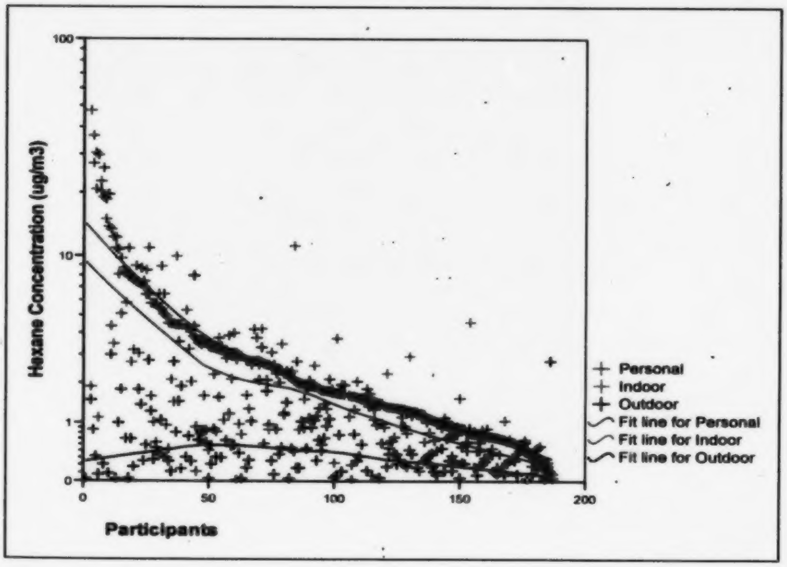


Figure 29 shows a moderate relationship between measures of indoor and personal concentration. There appears to be no correlation between outdoor sources and personal exposure.

Figure 29: Relationship between Exposures to Hexane by Sampler Site



3-Methylhexane

Methylhexane is an isomer of heptane, which means it has the same chemical formula as heptane but the atoms in the molecule are arranged differently. Methylhexane is colourless with a gasoline like odour and is commonly found in paint and solvents. The MDL for 3-methylhexane is 0.51 µg/m^3 and in the exposure monitors deployed 5.7% of personal, 29% of indoor, and 81.3% of outdoor samplers were below the detection limit.

Figure 30 shows the cumulative distribution of 3-methylhexane concentrations for the three types of samplers (personal, indoor, and outdoor). Personal and indoor concentrations were much higher than outdoor concentrations which provides insight into the source of exposure of 3-methylhexane.

Figure 30: Distribution of 3-Methylhexane

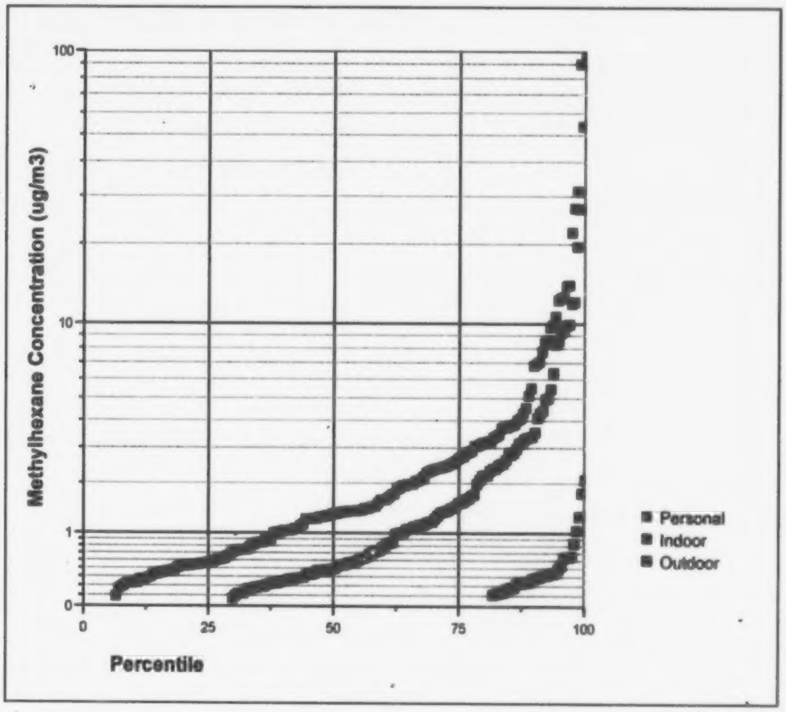


Figure 31 indicates there does not appear to be a seasonal trend affecting rate of personal exposure.

Figure 31: Temporal Trend in 3-Methylhexane Concentration

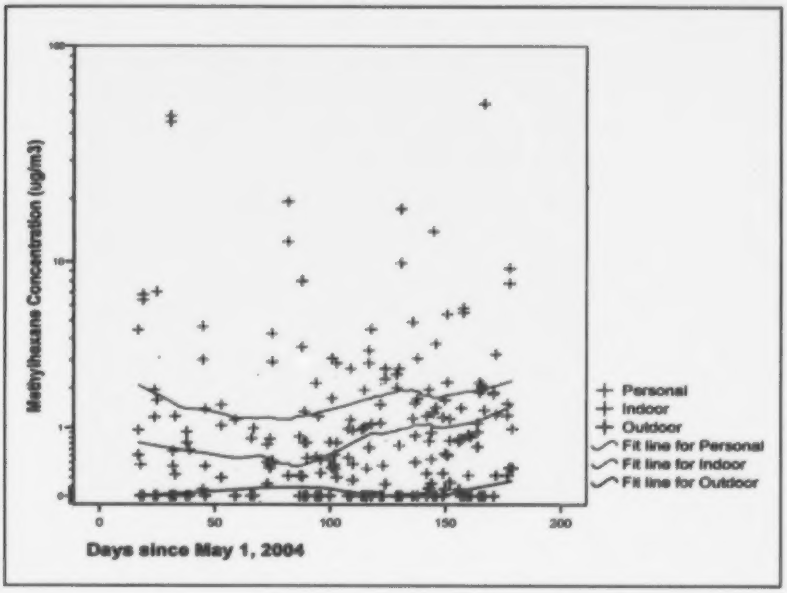
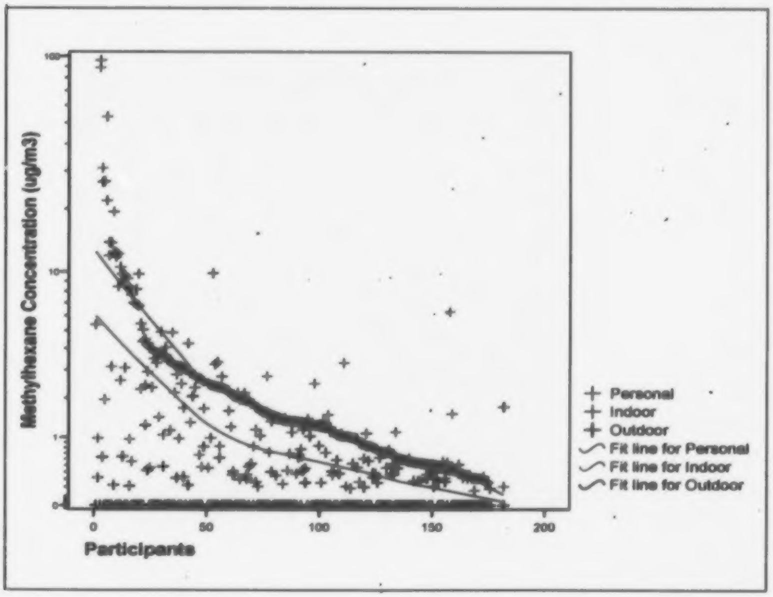


Figure 32 shows a moderate relationship between personal and indoor exposure concentrations such that high levels of personal exposure are consistently associated with higher levels of indoor exposure concentrations. There is no relationship between outdoor exposures and personal exposures.

Figure 32: Relationship between Exposures to 3-Methylhexane by Sampler Site



Benzene

Benzene is found in the combustion of petroleum fuels by motor vehicle engines and emissions associated with many industrial activities including wood processing, coal mining, textile manufacture and processes in the oil and gas industry. Another important source is cigarette smoke which makes a significant contribution to personal exposure. Benzene is a known carcinogen and appears on Health Canada's First Priority Substance List. The MDL of benzene is 0.42 µg/m^3 with all personal monitors detecting benzene at higher levels than the detection limit. The percentage of indoor and outdoor monitors below MDL was 2.6 % and 7.8% respectively.

Figure 33 shows the cumulative distribution of benzene concentrations for the three types of samplers (personal, indoor, and outdoor). Personal concentration appears to be derived from a cumulative effect of indoor and outdoor concentrations.

Figure 33: Distribution of Benzene

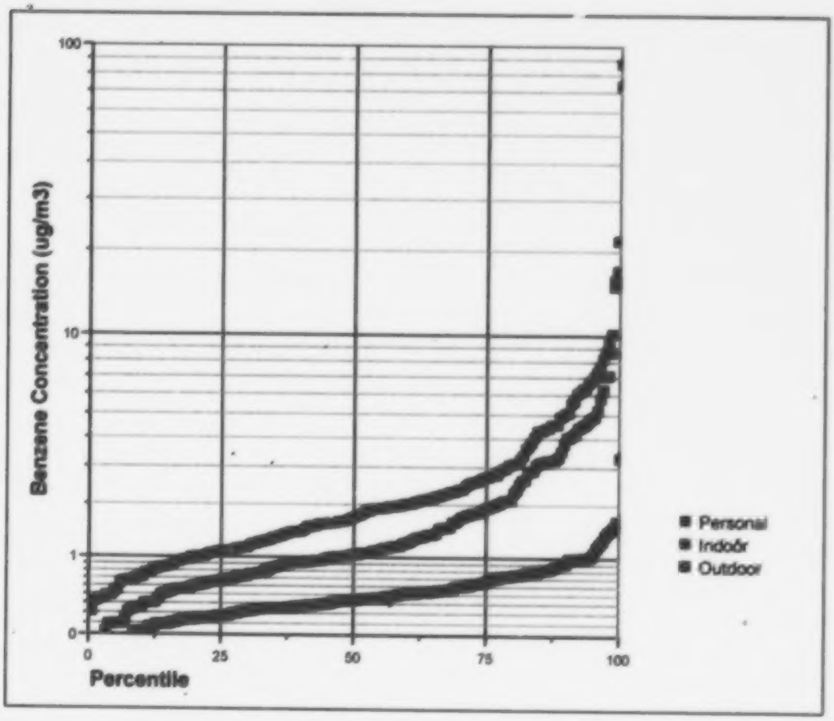


Table 12 contains a summary of the benzene measures taken during the program showing the median and 95th percentile levels (µg/m^3) compared to guidelines and levels at other CEHEAP communities. In a previous CEHEAP community, Lethbridge, a low number of samplers were used therefore estimates of median indoor and outdoor levels were not reliable. In the Wabamun area, outdoor benzene levels were low and similar to other studies completed in Alberta. The median personal levels were roughly 4 times the outdoor levels and approximately 10% of the levels reported in the TEAM study. The TEAM study also found that the highest levels of benzene were from the personal samplers, followed by the indoor sampler levels, while the outdoor samplers contained the lowest levels of benzene.[34]

Table 12: Comparison of Benzene Levels in µg/m^3 with Guidelines and Other Studies[35,36,37]

Parameter	Personal	Indoor	Outdoor	Ambient Station	P/I ratio	P/O ratio	I/O ratio
Wabamun Median	1.72	1.04	0.44	N/A	1.65	3.9	2.36
Wabamun 95th	7.21	5.02	1.12	N/A	1.44	6.44	4.48
Fort Saskatchewan Median	1.55	0.29	0.61	N/A	1.72	2.54	1.48
Fort Saskatchewan 95th	7.10	4.36	1.36	N/A	1.63	5.22	3.21
Grande Prairie Median	1.45	0.89	0.52	N/A	1.63	2.79	1.71
Grande Prairie 95th	7.53	4.89	1.61	N/A	1.54	4.67	3.03
Fort McMurray Median	2.80	1.7	1.3	1.2	1.7	2.05	1.23
Fort McMurray 95th	10.0	6.6	5.5	3.1	1.5	0.82	1.20
Lethbridge Median	2.10	*	*	N/A	N/A	N/A	N/A
Lethbridge 95th	6.70	4.8	3.6	N/A	1.4	1.90	1.34
Relevant Studies	15 (TEAM)[i]	10 (TEAM)[i]	2.6[ii]	4.4 (urban) 0.6 to 1.2 (rural)[i]	1.5[i]	2.5[i]	1.7[i]
Guideline/Reference Level	N/A	N/A	30 (hour)[iii]	16 UK current 3.2 UK future	N/A	N/A	N/A

* Estimate not available due to small number of Lethbridge samples.

i: Wallace, 1996.

ii: Median value from monitoring across Canada (Dann et al., 1995).

iii: Alberta's Ambient Air Quality Objectives, 2005

Figure 34 shows a minimal temporal trend in benzene concentrations.

Figure 34: Temporal Trend in Benzene Concentration

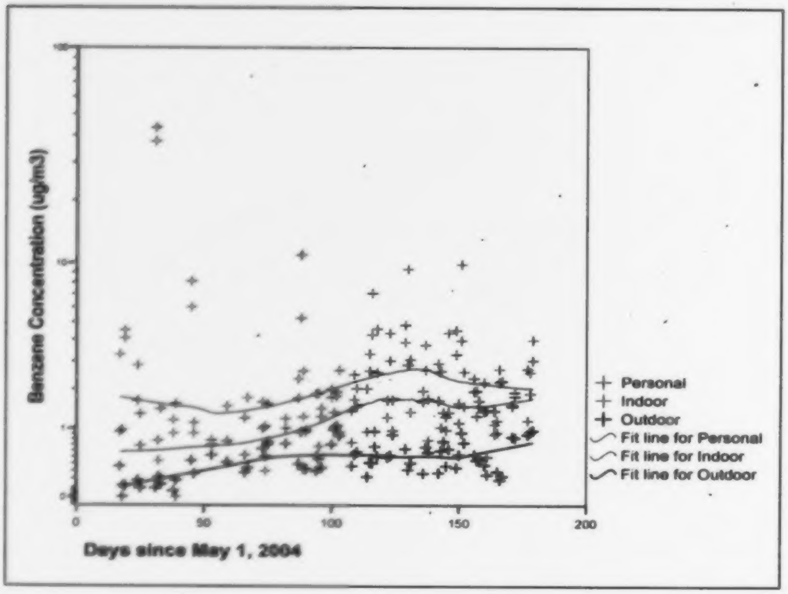
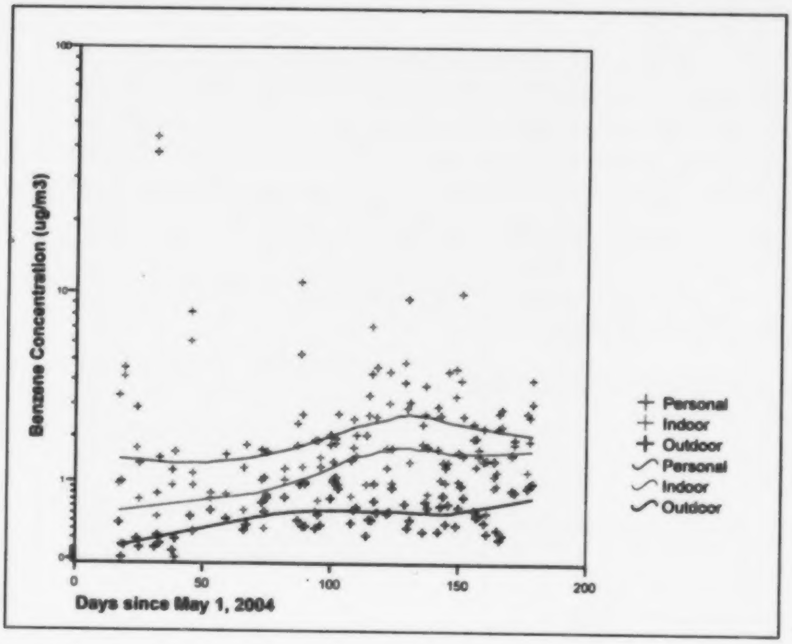


Figure 35 shows the relationships between concentrations monitored personally, indoors, and outdoors. The graph shows a moderate relationship between personal and indoor exposure concentrations such that high levels of personal exposure are consistently associated with higher levels of indoor exposure concentrations. There appears to be no direct relationship between personal and outdoor concentrations except causing a cumulative effect.

Figure 35: Relationship between Exposures to Benzene by Sampler Site



Heptane

Heptane like its isomer methylhexane is colorless and has a gasoline-type odor. Heptane is used as a solvent in glues, varnishes, cements and inks many of which are found in people's homes or work. It is also a major ingredient in gasoline and aviation fuel and in petroleum solvents such as petroleum naphtha and rubber solvent. The MDL of heptane is 0.51µg/m^3 with 12.0% personal and 28.0% indoor monitors detecting concentrations below this limit. Over three-quarters of the outdoor monitors (77.6%) reported levels below the MDL.

Figure 36 shows the cumulative distribution of heptane concentrations for the three types of samplers (personal, indoor, and outdoor). Personal and indoor concentrations follow similar trends and were much higher than outdoor concentrations.

Figure 36: Distribution of Heptane

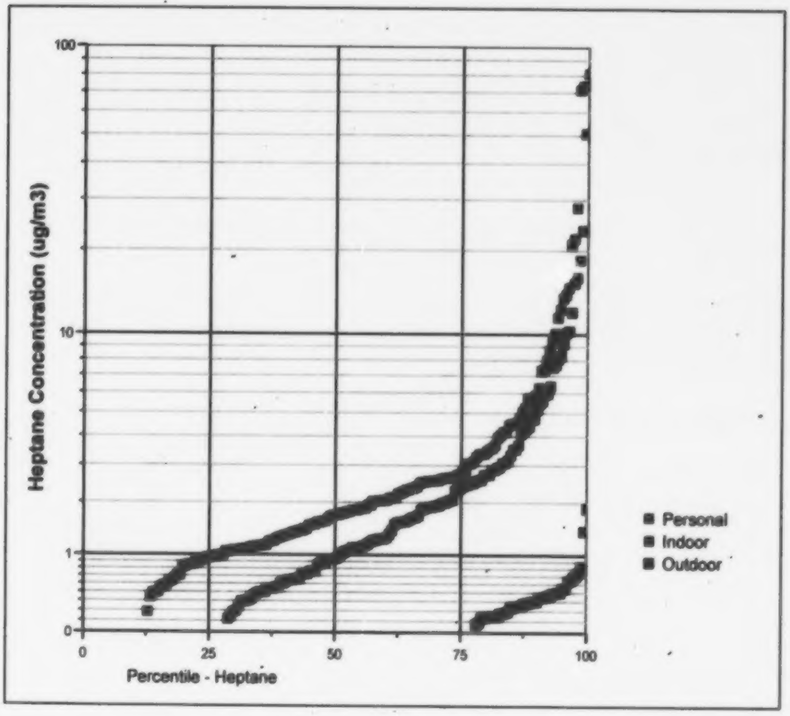
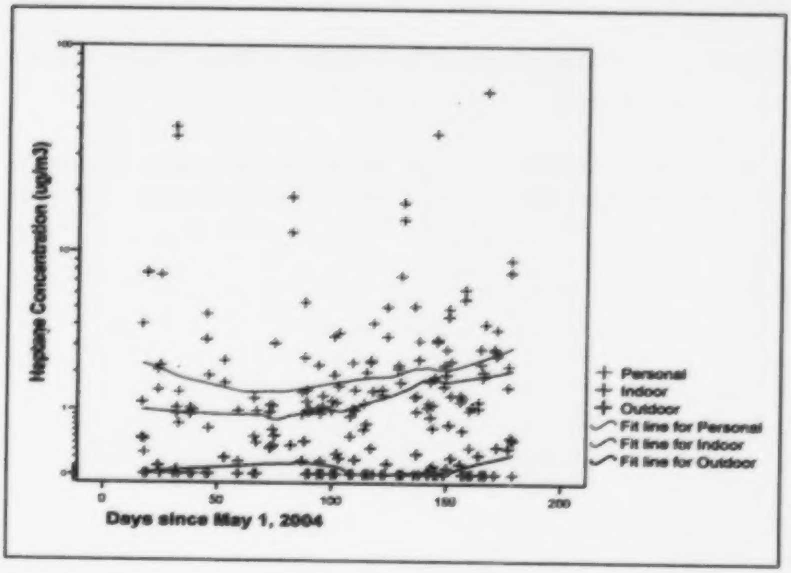


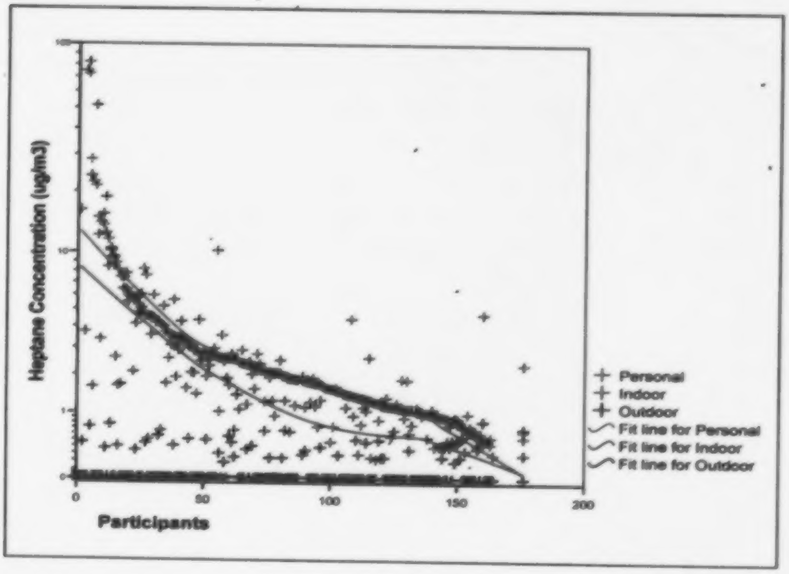
Figure 37 shows the temporal trend in heptane concentrations. With few outdoor monitors over the MDL, there is insufficient data to conclude that heptane concentrations may differ across the seasons.

Figure 37: Temporal Trend in Heptane Concentration



A moderately strong relationship between personal and indoor exposure concentrations is demonstrated in Figure 28. Like other VOCs, high levels of personal exposure to heptane are consistently associated with higher levels of indoor exposure concentrations.

Figure 38: Relationship between Exposures to Heptane by Sampler Site



Toluene

Toluene is used in the production of benzene and urethane and is also a gasoline additive. It is also used in the manufacture of explosives, dyes, cements, spot removers, cosmetics, antifreeze, asphalt and detergent. Like benzene, toluene also appears on Health Canada's First Priority Substances List. The MDL of toluene is 2.6 μg/m^3 with 3.1% of personal and 5.7% of indoor monitors below this limit. Similar to heptane, a high percentage (88%) of outdoor monitors had readings less than the MDL.

Figure 39 shows the cumulative distribution of toluene concentrations for the three types of samplers (personal, indoor, and outdoor). At the 50th percentile, personal and indoor concentrations are over an order of magnitude higher than outdoor concentrations. As a result, outdoor levels have little to no influence on personal exposure. This graph therefore identifies that personal exposure to toluene is associated with indoor levels in our homes.

Figure 39: Distribution of Toluene

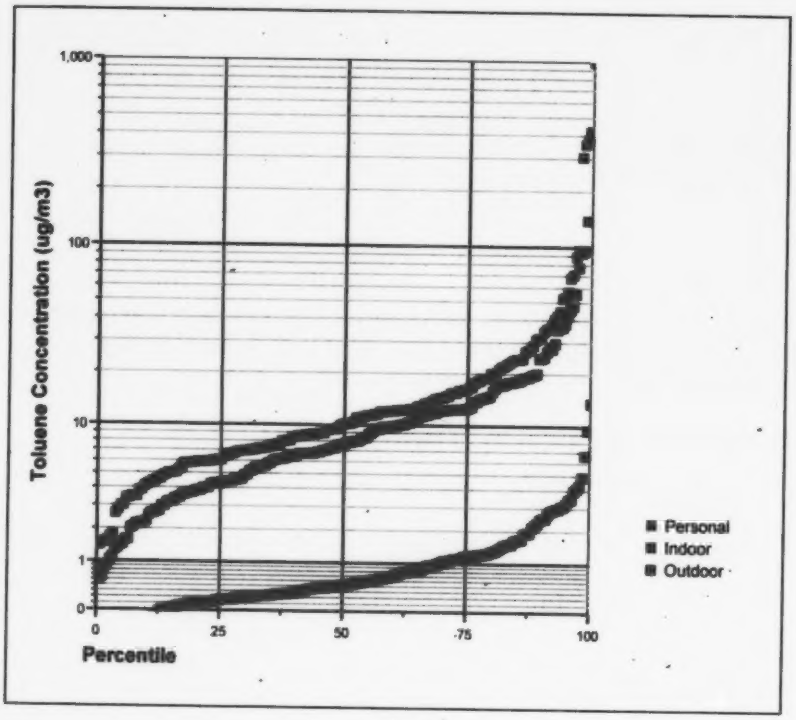


Figure 40 shows the temporal trend in toluene concentrations. There is insufficient evidence to conclude that concentrations differ across the seasons.

Figure 40: Temporal Trend in Toluene Concentration

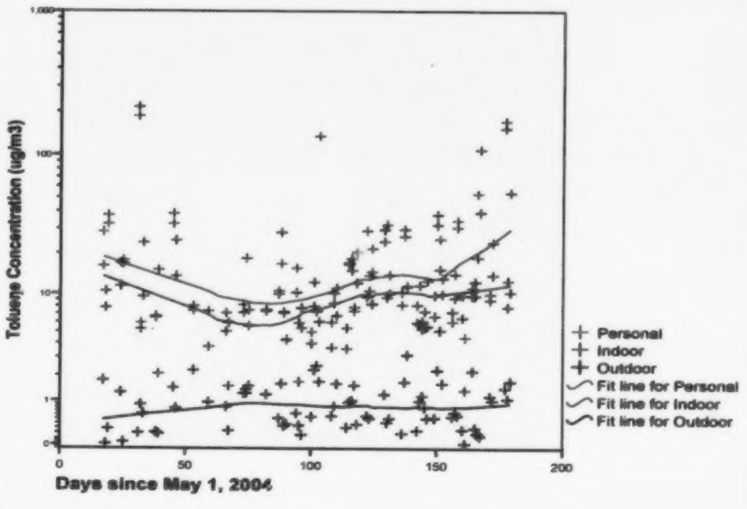
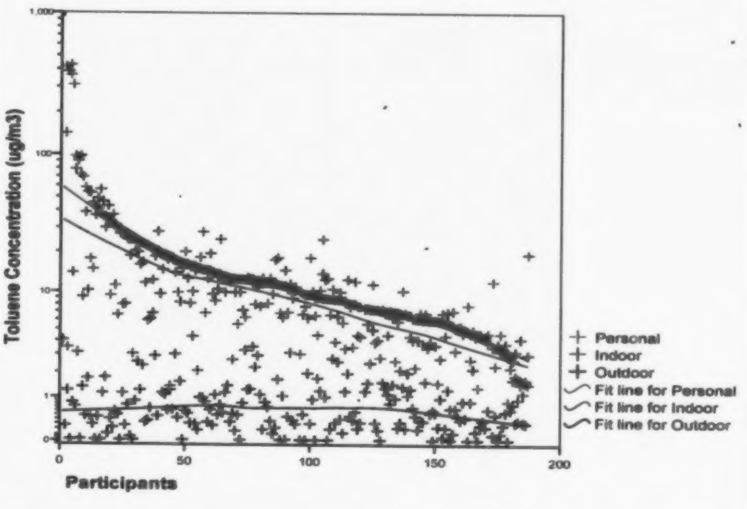


Figure 41 shows a strong relationship between personal exposure and indoor exposure concentrations implying that high levels of personal exposure are consistently associated with higher levels of indoor exposure concentrations. There is no relationship between personal and outdoor exposures.

Figure 41: Relationship between Exposures to Toluene by Sampler Site



Octane

Octane is a well known component of gasoline but other sources include aerosol paint concentrates, eye preparations (mascara, eye shadow), furniture polish and cleaners. It is also found in all types of paint and paint thinners, wood office furniture, photocopying machines and work surfaces (modular systems). The MDL for is 0.56 μg/m^3 with 7.3% of personal and 14.0% of indoor below this limit. For the outdoor monitors, a high percentage (88%) of the monitors was below the MDL.

Figure 42 shows the cumulative distribution of octane concentrations for the three types of samplers (personal, indoor, and outdoor). Personal and indoor levels appear to be very correlated indicating that indoor sources of octane equate to personal exposure. As a low percentage of outdoor monitors detected octane above the MDL, personal exposure does not appear to be affected by outdoor concentrations.

Figure 42: Distribution of Octane

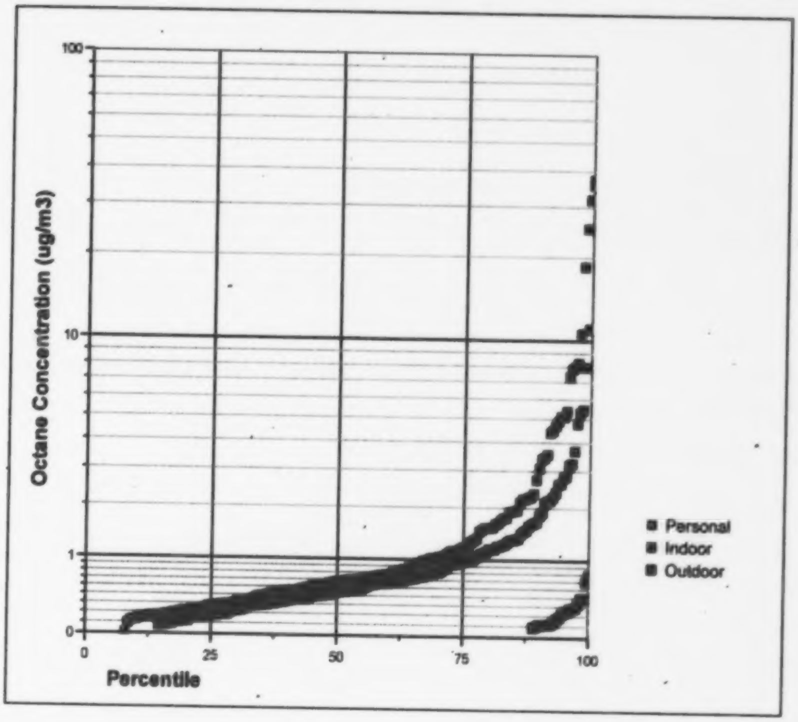


Figure 43 shows the temporal trend in octane concentrations. As there are a low percentage of outdoor monitors over the MDL, there is insufficient evidence to conclude that concentrations differ across the seasons.

Figure 43: Temporal Trend in Octane Concentration

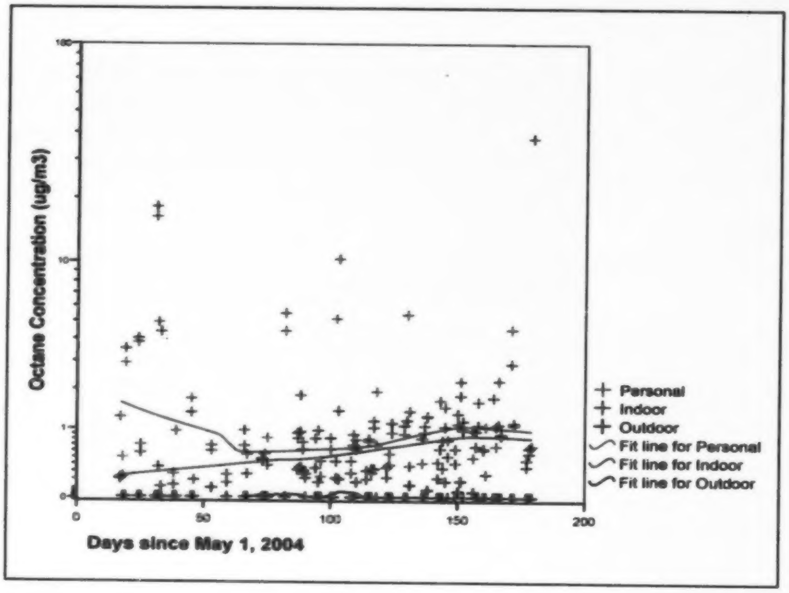
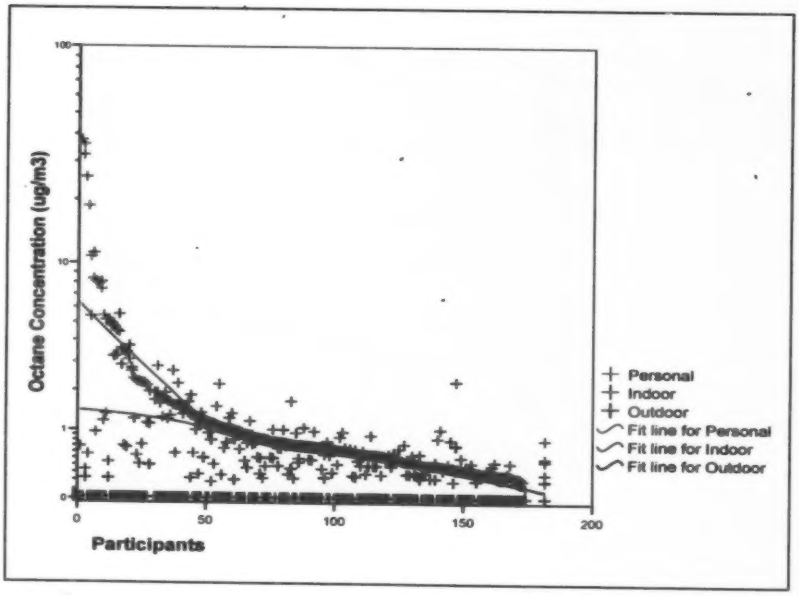


Figure 44 shows a strong relationship between personal and indoor exposure concentrations, but no relationship with outdoor concentrations.

Figure 44: Relationship between Exposures to Octane by Sampler Site



Ethylbenzene

Ethylbenzene is used primarily in the production of styrene, a hydrocarbon used to make synthetic rubbers and plastics. It is also a solvent in paints and varnishes, household cleaning products, gasoline, pesticides, carpet glues, asphalt and tobacco smoke. For this analysis, the MDL is 0.55 μg/m^3 with 2.1% of personal and 14.0% of indoor samples below this detection limit. A high percentage of outdoor monitors (87.5%) were below the detection limit.

Figure 45 shows the cumulative distribution of ethylbenzene concentrations for the three types of samplers (personal, indoor, and outdoor). Personal exposure appears to be linked to indoor concentrations as can be seen in the distribution. As a low percentage of outdoor monitors detected ethylbenzene above the MDL, personal exposure does not appear to be affected by outdoor concentrations.

Figure 45: Distribution of Ethylbenzene

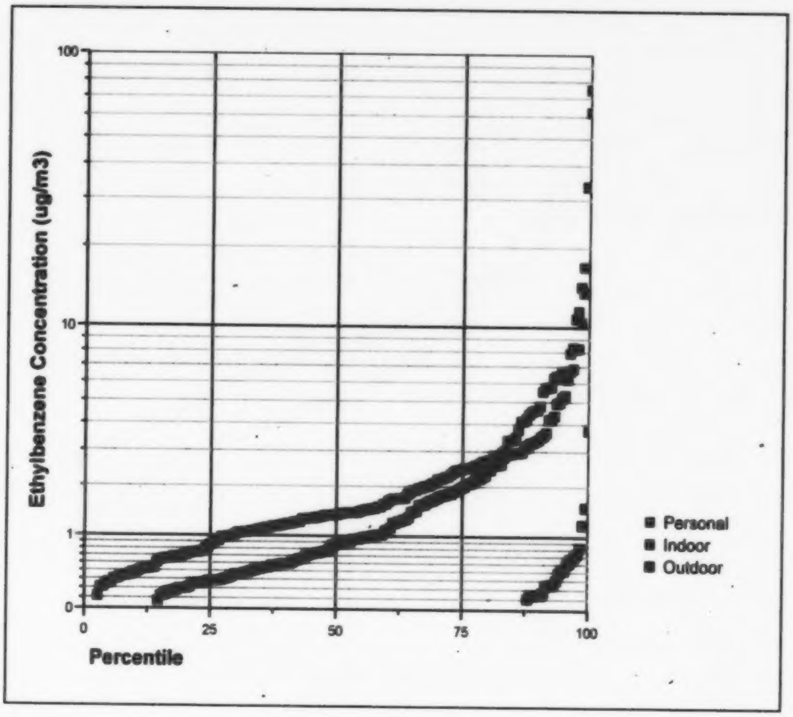


Figure 46 shows the temporal trend in ethylbenzene concentrations. As there are a low percentage of outdoor monitors over the MDL, there is insufficient evidence to conclude that concentrations differ across the seasons.

Figure 46: Temporal Trend in Ethylbenzene Concentration

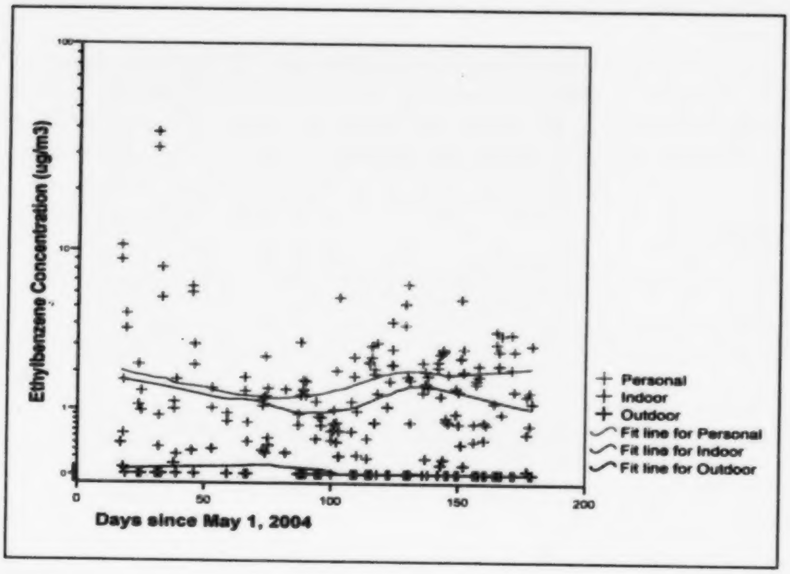
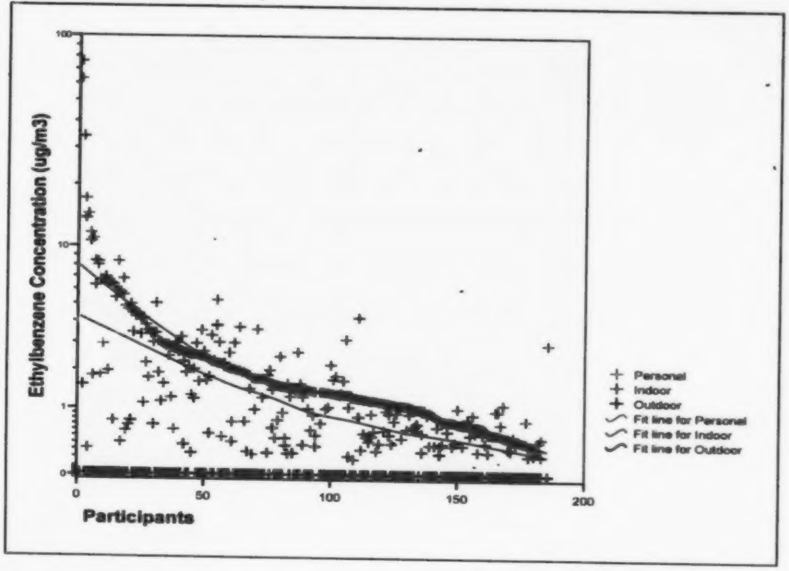


Figure 47 shows a strong relationship between personal and indoor exposure concentrations but no relationship between personal and outdoor exposures concentrations.

Figure 47: Relationship between Exposures to Ethylbenzene by Sampler Site



m-,p-Xylene

Major environmental releases of xylene are due to emissions from petroleum refining, chemical plants and automobile exhaust. Xylenes are also found in a variety of consumer products including gasoline, paint, paint thinners and cigarette smoke. The MDL for *m-, p-* xylene is 1.0 µg/m^3 with 1.0% of personal and 5.7% of indoor monitors less than this detection limit. The outdoor fraction of samples below the MDL is 63.5%.

Figure 48 shows the cumulative distribution of m-, p-xylene concentrations for the three types of samplers (personal, indoor, and outdoor). Personal exposure appears to be strongly related to indoor concentrations whereas outdoor concentrations have little influence.

Figure 48: Distribution of *m-, p-* Xylene

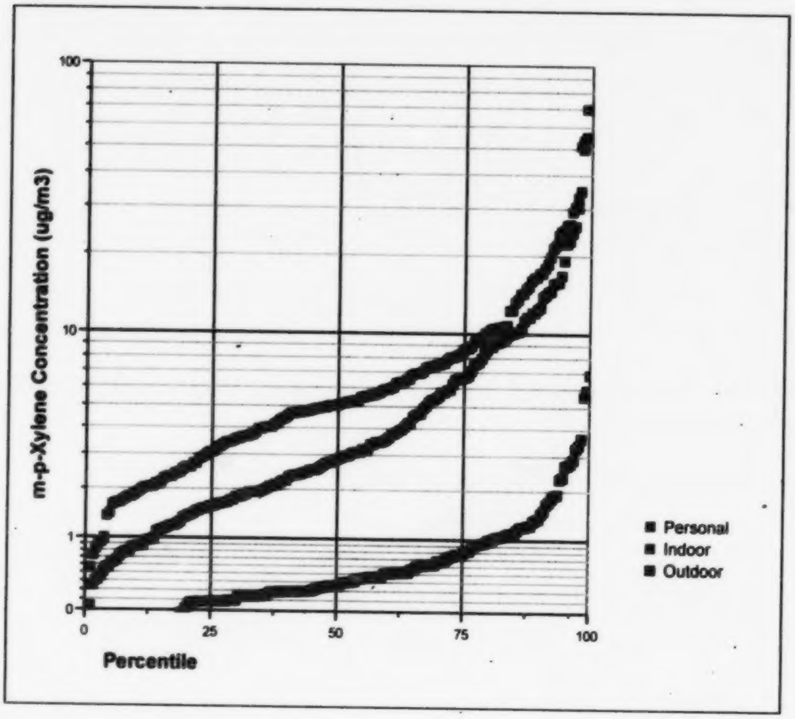


Figure 49 shows the temporal trend in *m*-, *p*-xylene concentrations. There appears to be no apparent seasonal trend to this contaminant.

Figure 49: Temporal Trend in *m*-, *p*-xylene Concentration

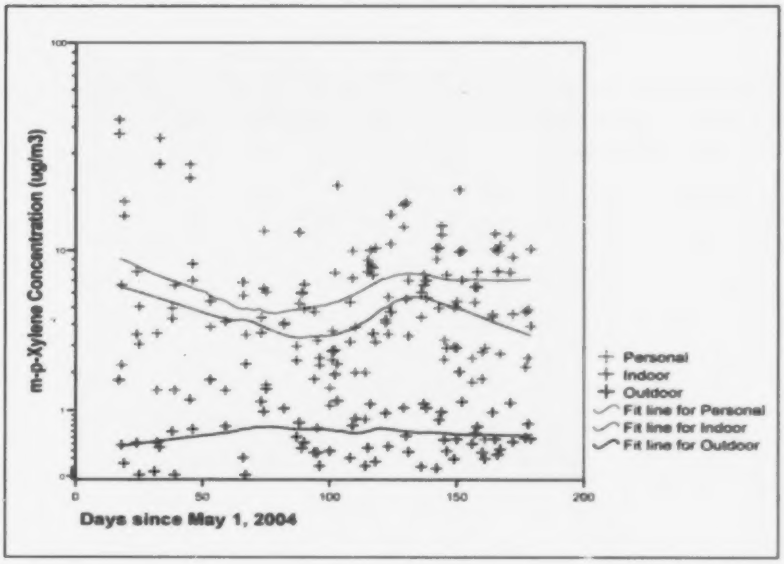
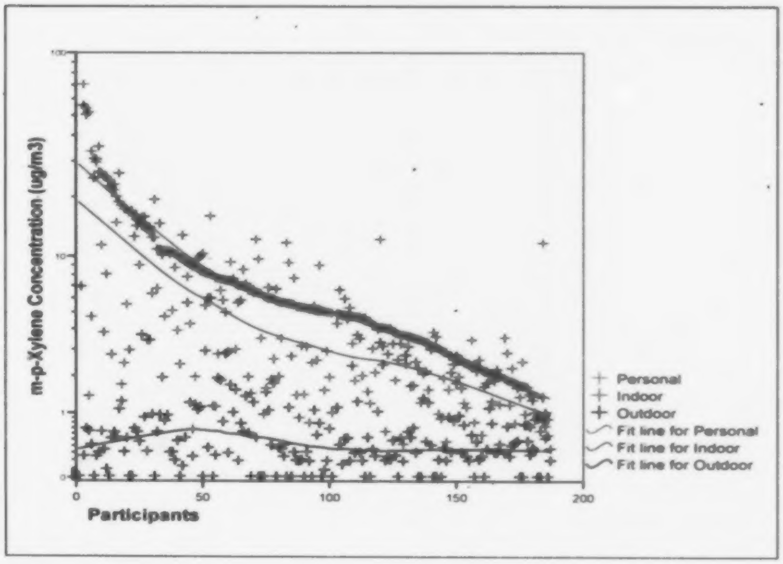


Figure 50 shows a good relationship between personal and indoor exposure concentrations but no relationship to outdoor exposure concentrations.

Figure 50: Relationship between Exposures to *m*-, *p* - Xylene by Sampler Site



o -Xylene

This second type of xylene is found in the same environmental releases as *m-*, *p*-xylene such as petroleum refining, chemical plants, automobile exhaust and as a solvent. Likewise, it is found in a variety of consumer products including gasoline, paint, paint thinners and removers, rust preventatives and cigarette smoke. Any type of xylene appears on Health Canada's First Priority Substance List. The MDL for *o*-xylene is 0.55 µg/m^3 with 3.6% of personal and 14.5% of indoor monitors less than this level. A high fraction of the outdoor monitors, 83.9% were less than the MDL.

Figure 51 shows the cumulative distribution of *o*-xylene concentrations for the three types of samplers (personal, indoor, and outdoor). Personal exposure appears to be related to indoor exposure with little effect seen from outdoor concentrations.

Figure 51: Distribution of *o*-Xylene

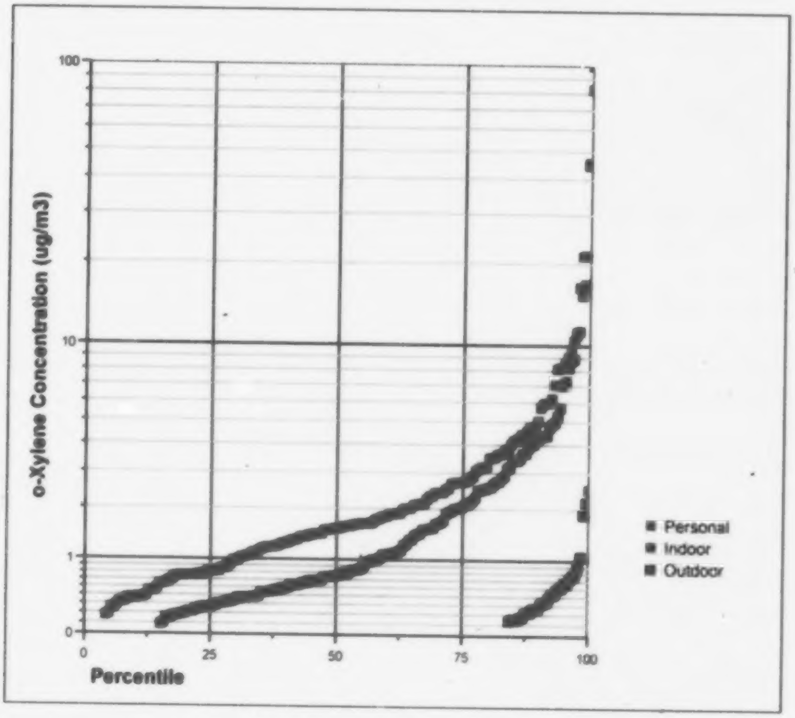


Figure 52 shows the temporal trend in o-xylene concentrations. There appears to be no apparent seasonal trend for this VOC.

Figure 52: Temporal Trend in *o*-Xylene Concentration

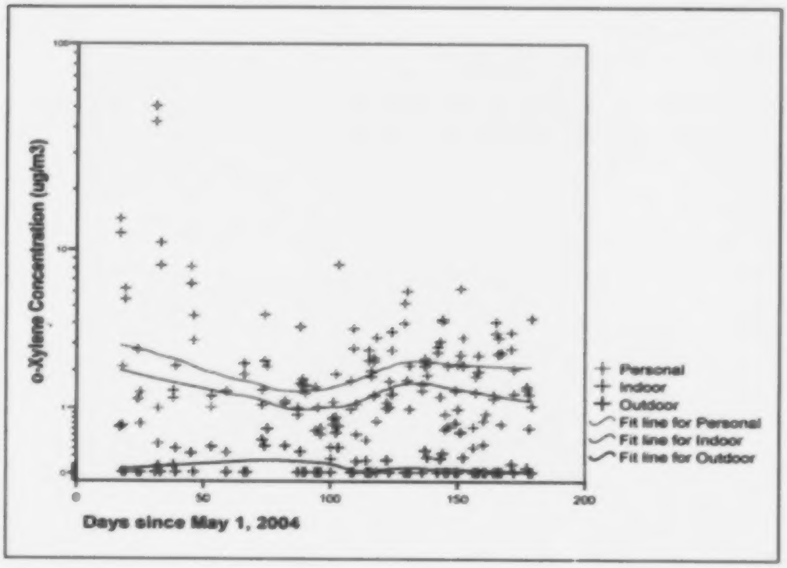
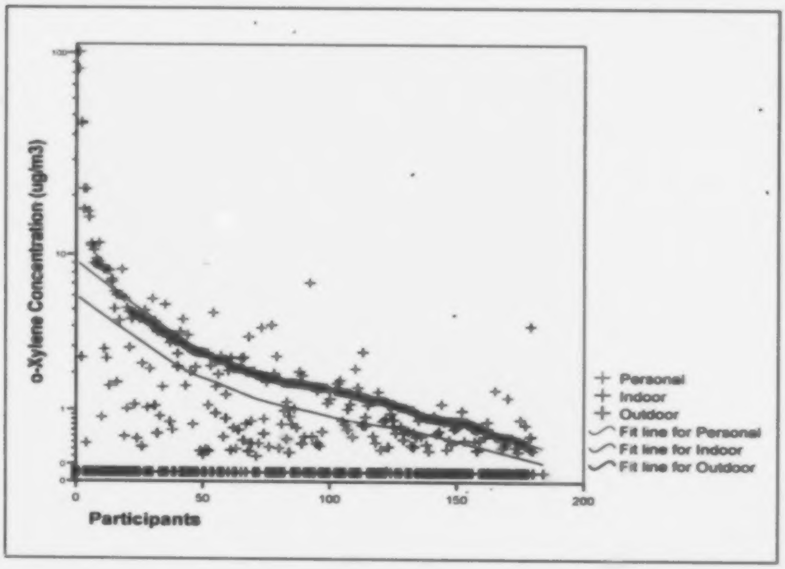


Figure 53 shows a strong relationship between personal and indoor exposure concentrations but no relationship between personal exposures and outdoor exposures.

Figure 53: Relationship between Exposures to *o*-Xylene by Sampler Site



Nonane

Nonane is colorless and is an important component of gasoline and petroleum solvents. It is also used in the manufacture of paraffin products, paper processing and rubber industry and synthesis of biodegradable detergents. The MDL for nonane is 0.60 μg/m^3 with a high fraction of all samples less than this limit. The proportions were as follows: 27.1% for personal, 41.5% for indoor and 96.9% for outdoor.

Figure 54 shows the cumulative distribution of nonane concentrations for the three types of samplers (personal, indoor, and outdoor). Personal concentrations were slightly higher than indoor concentrations suggesting the correlation between an indoor and personal source. Very few outdoor samplers recorded detectable nonane.

Figure 54: Distribution of Nonane

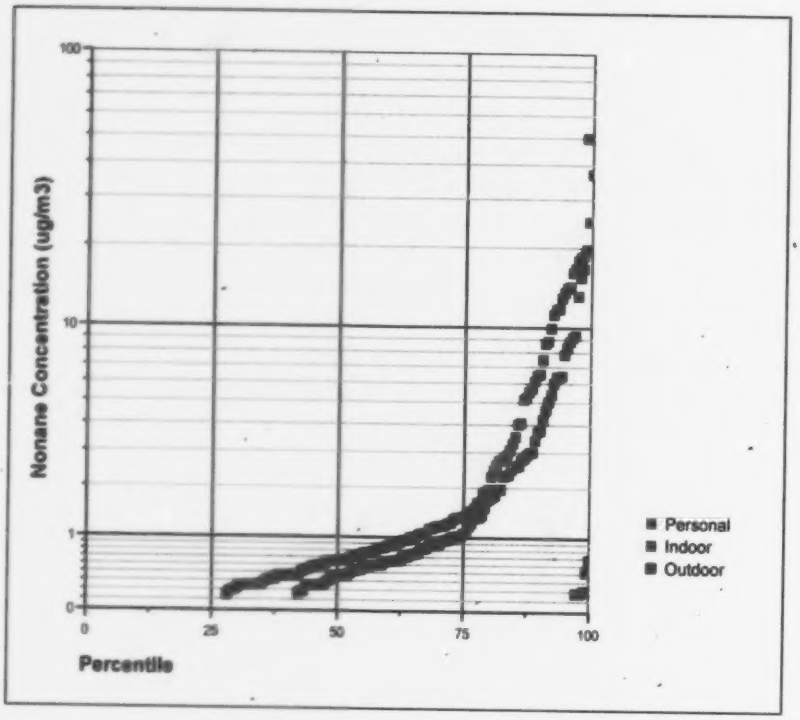
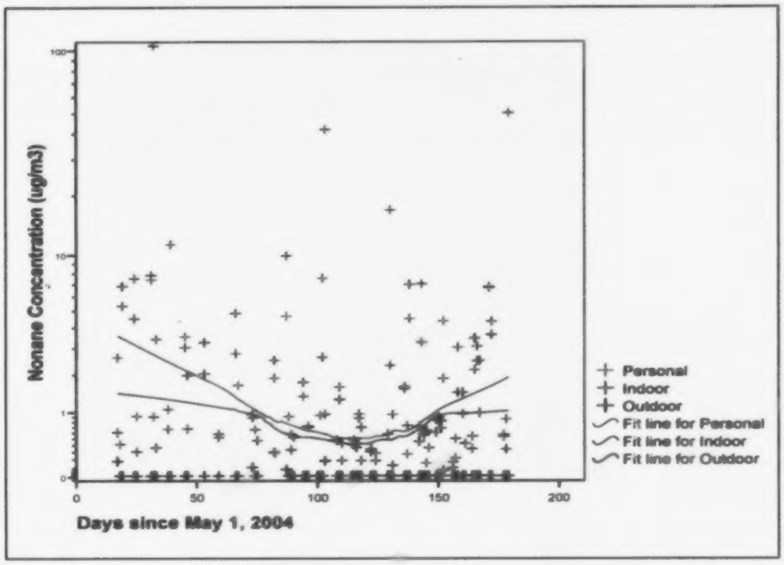


Figure 55 shows the temporal trend in nonane concentrations. There is insufficient evidence to conclude that concentrations differ across the seasons, though nonane levels may decrease in the summer for unknown reasons.

Figure 55: Temporal Trend in Nonane Concentration



As demonstrated for other VOCs, a third graph labelled "*Relationship between Exposure to Nonane by Sampler Site*" normally would be created. As the fraction of outdoor samplers below the MDL is high (96.9%), there is insufficient data to calculate the relationship between exposure and sampler site.

Decane

Decane like many VOCs has a gasoline odor, and its vapor which is heavier than air may spread long distances and accumulate in low-lying areas. It is a component of gasoline, jet fuel, and kerosene and is used in the rubber and paper industries. The MDL for decane is 0.64 μg/m³ with 9.9% of personal monitors and 17.6% of indoor samplers below this limit. The fraction of outdoor samples less than the MDL is 73.4%.

Figure 56 shows the cumulative distribution of decane concentrations for the three types of samplers (personal, indoor, and outdoor). Similar to other VOCs, personal exposure concentrations appear to be highly related to indoor exposure concentrations with little to no effect seen from outdoor sources.

Figure 56: Distribution of Decane

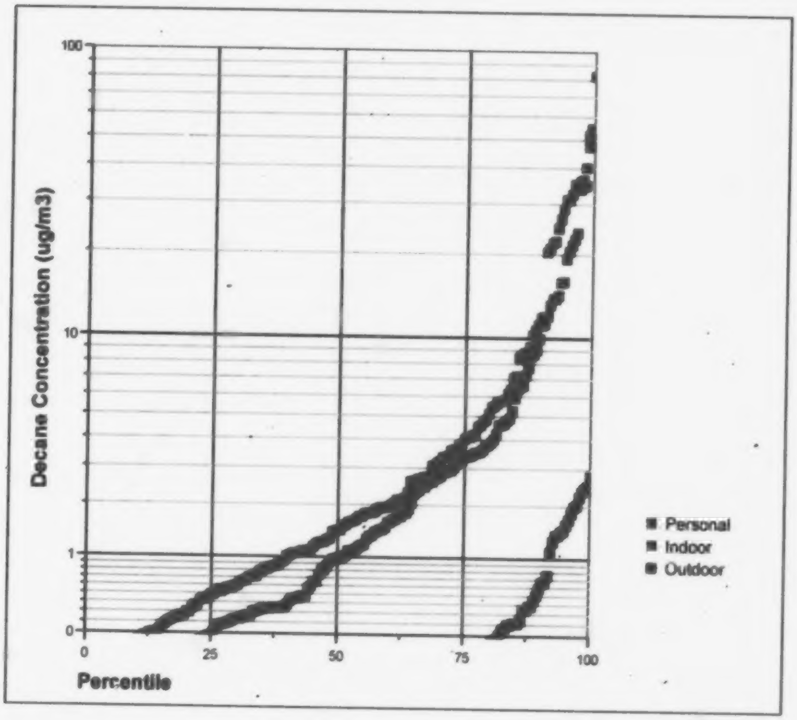


Figure 57 shows a decrease in decane exposure in late summer, but there is insufficient data to conclude how concentrations may differ overall across seasons.

Figure 57: Temporal Trend in Decane Concentration

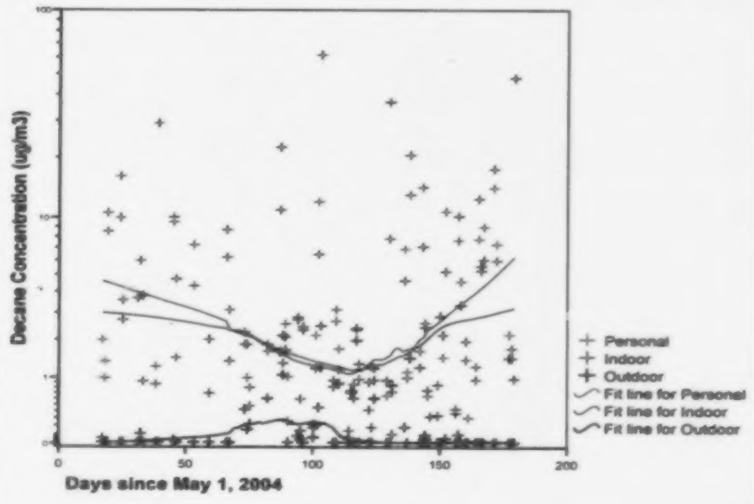
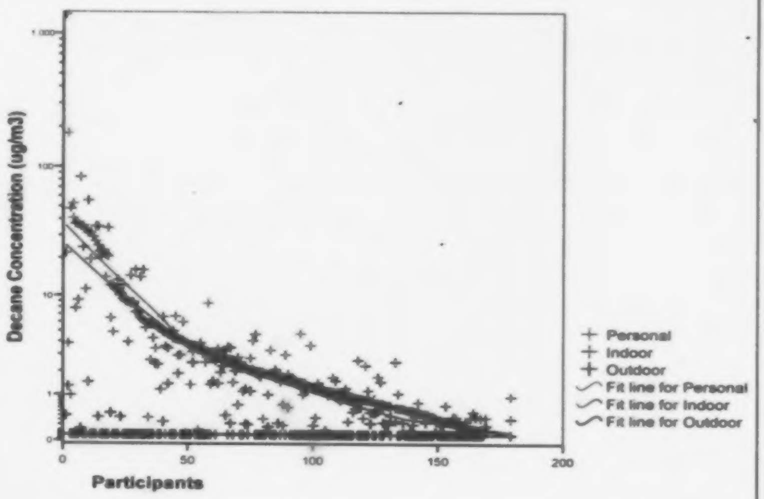


Figure 58 identifies a very strong relationship between personal and indoor exposure concentrations such that the levels of personal exposure detected are consistently associated with the levels of indoor exposure concentrations. There is no relationship between outdoor exposures and personal exposures.

Figure 58: Relationship between Exposures to Decane by Sampler Site



Limonene

Limonene is classified chemically as a terpene. Terpenes are produced primarily by plants as an essential oil and usually have a citric or lemon-orange fragrance. In addition to being found as odorants in cleaning products and air fresheners, they are often emitted by wood products and solvents based on pine oil. In industry, limonene is an environmentally friendly alternative to mineral oils as a solvent for cleaning purposes, being more easily biodegradable and produced from a renewable source. The MDL for limonene is 0.50 $\mu g/m^3$ with only a minority of personal (0.5%) and indoor (1.6%) samplers' not detecting limonene. The fraction of outdoor samplers not detecting limonene was moderate at 67.7%.

Figure 59 shows the cumulative distribution of limonene concentrations for the three types of samplers (personal, indoor, and outdoor). The concentrations of personal and indoor monitors are very similarly distributed indicating personal exposure is related to indoor concentrations.

Figure 59: Distribution of Limonene

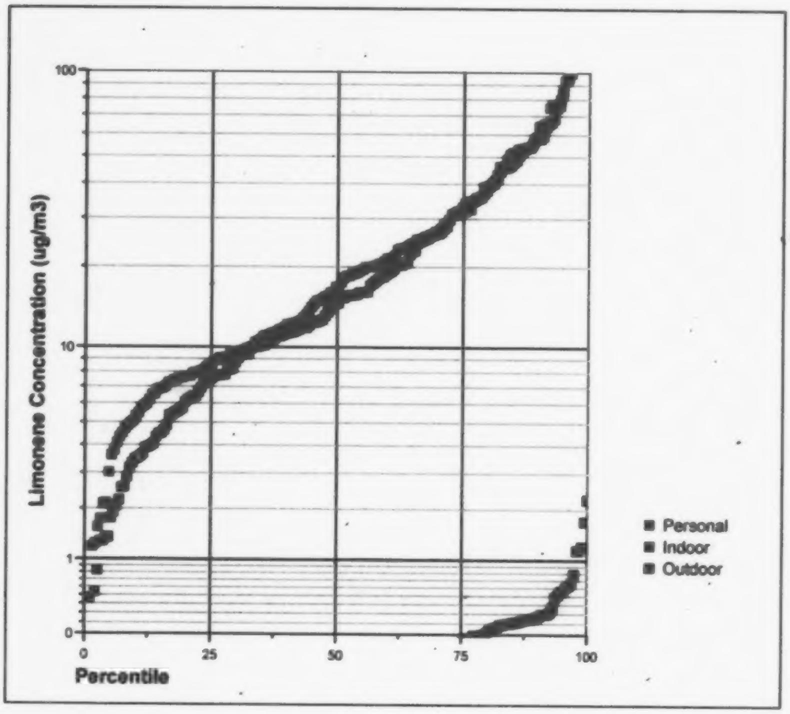


Figure 60 shows the temporal trend in limonene concentrations where there is insufficient evidence that concentrations differ across the seasons.

Figure 60: Temporal Trend in Limonene Concentration

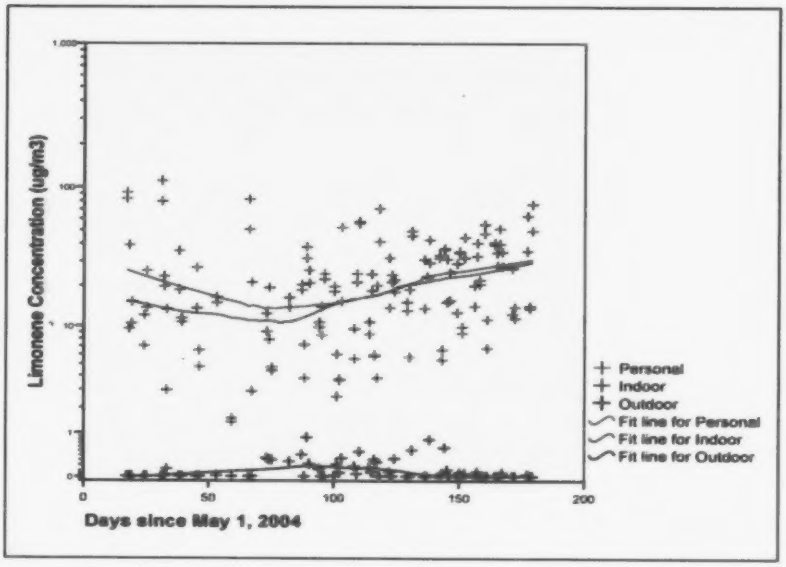
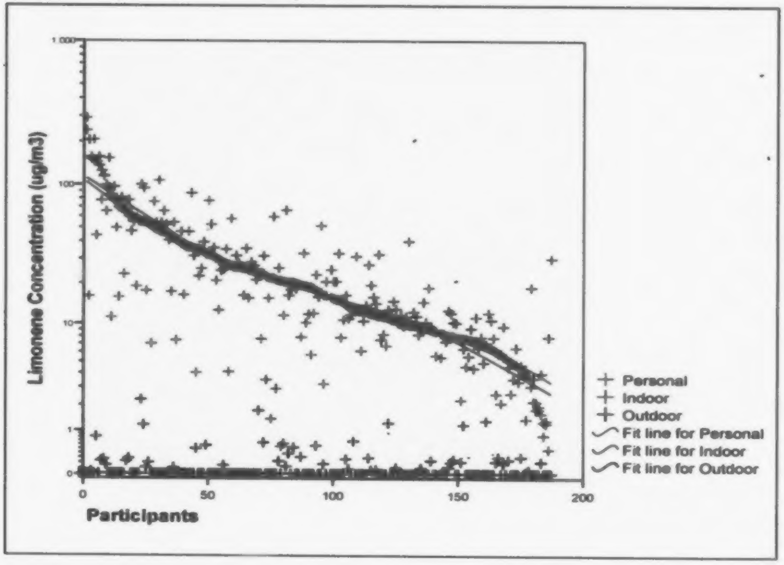


Figure 61 identifies a very strong relationship between personal and indoor exposure concentrations such that high levels of personal exposure are consistently associated with higher levels of indoor exposure concentrations. There is no relationship between outdoor exposures and personal exposures.

Figure 61: Relationship between Exposures to Limonene by Sampler Site



N-propylbenzene

N-propylbenzene is found naturally in petroleum and bituminous coal but is released to the atmosphere in emissions from combustion sources such as incinerators, gasoline and diesel engines. It is also found in building and construction insulation, floor and wall covering, scatter rugs, bathmats and wood office work surfaces. The MDL is 0.60 µg/m^3 with 31.8% of personal, 46.1% of indoor and 90.6% of outdoor monitors below this detection limit.

Figure 62 shows the cumulative distribution of *N*-propylbenzene concentrations for the three types of samplers (personal, indoor, and outdoor). Despite the low fraction of monitors detecting this VOC, the distribution of personal and indoor concentrations follow similar trends indicating personal exposure may be related to indoor concentrations.

Figure 62: Distribution of *N*-propylbenzene

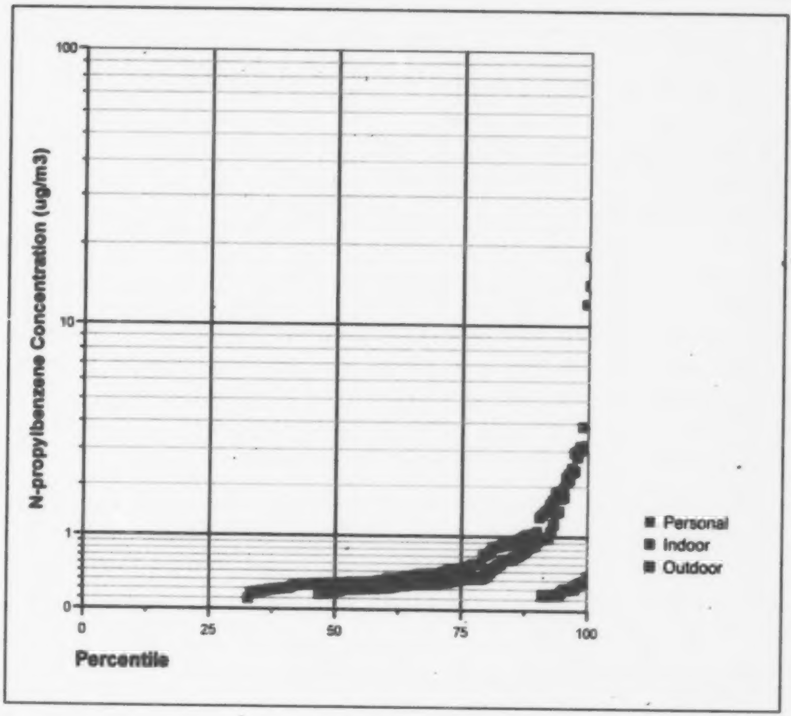


Figure 63 shows the temporal trend in *N*-propylbenzene concentrations. There is insufficient evidence to conclude that concentrations differ across the seasons.

Figure 63: Temporal Trend in *N*-propylbenzene Concentration

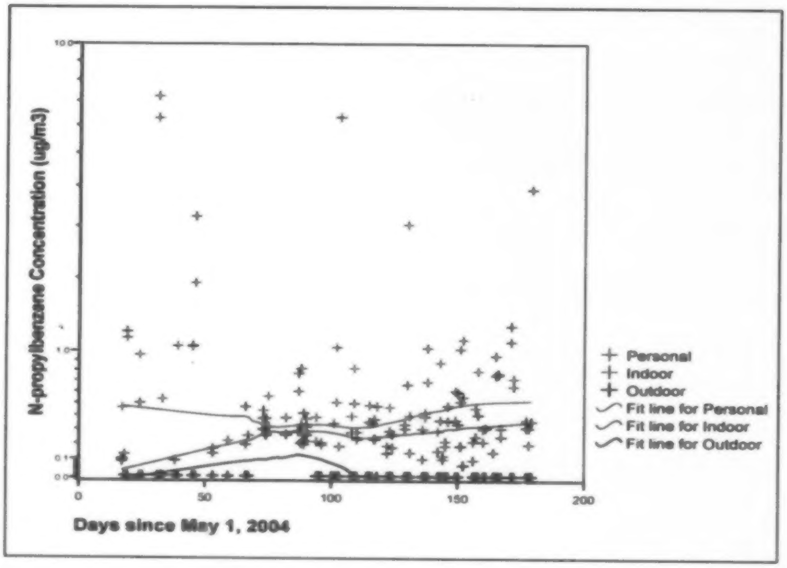
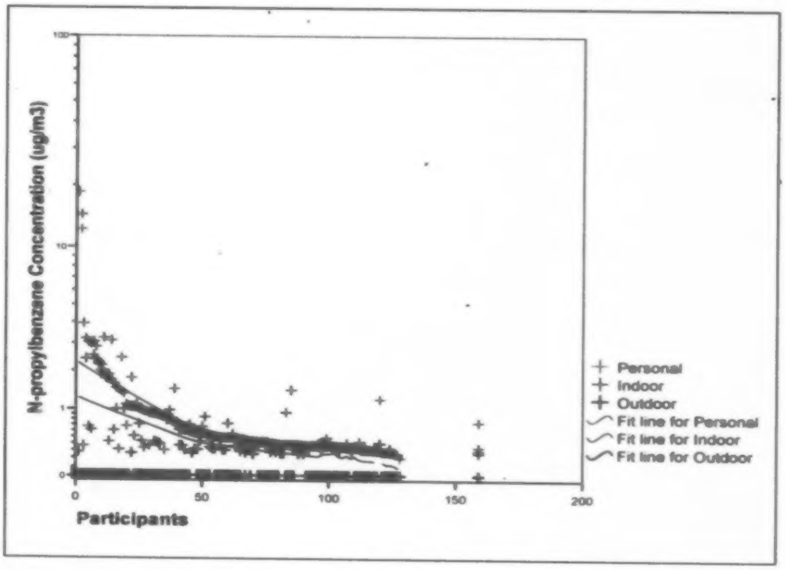


Figure 64 shows the relationships between concentrations monitored personally, indoors, and outdoors. A strong relationship exists between personal and indoor exposure concentrations similar to other previously discussed. There is no relationship between outdoor exposures and personal exposures.

Figure 64: Relationship between Exposure to *N*-propylbenzene by Sampler Site

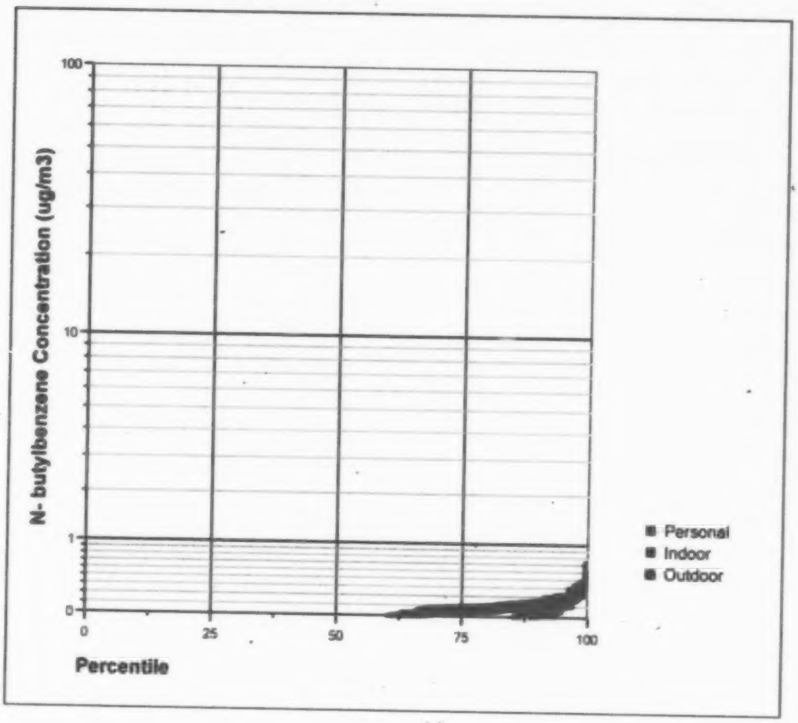


N-butylbenzene

N-butylbenzene is colorless with an aromatic odor which resembles an alcoholic odor. In industry, it is used as a specialty solvent and in the production of other chemicals. Household uses or sources include insecticides, printing, painting, perfume and in the production of Ibuprofen. The MDL for *N*-butylbenzene is 0.66 µg/m^3 with a high portion of personal (88.5%) and indoor (84.5%) samplers below this limit. For outdoor monitors, 55.2% were below the MDL.

Figure 65 shows the cumulative distribution of *N*-butylbenzene concentrations for the three types of samplers (personal, indoor, and outdoor). The numbers of personal and indoor concentrations is extremely low and are indistinguishable between each other as shown in this figure. While the frequency of outdoor concentrations was the highest, there is insufficient data to accurately describe the relationship between the three types of samplers. Therefore, further analysis of this VOC was not conducted.

Figure 65: Distribution of *N*-butylbenzene



7.2 Particulate Samplers

Particulate matter (PM) samples were also collected from selected participants in the Wabamun and area program. To determine exposure to particulate matter, air is actively collected or drawn by a pump onto a filter which is submitted for laboratory analysis. As with the PEMs, the particulate filters were deployed inside and outside the households, and operate in the area of the individual's breathing zone, and blanks were also completed for quality assurance and control purposes. Particulate matter samples were all of the $PM_{2.5}$ range (smaller air-borne particles less than 2.5μm in size) which can penetrate lung tissue. As with the PEMs, all samples were deployed for a consecutive 7-day period.

From each sample it was possible to determine the concentration of particles in the air. Each sample was also analyzed for a variety of metals. Table 13 shows the metals that were analyzed.

Table 13: Metals Analyzed from Particulate Samples

Standard Chemical Abbreviation	Chemical Name	Standard Chemical Abbreviation	Chemical Name
AG	Silver	MN	Manganese
AL	Aluminum	MO	Molybdenum
AS	Arsenic	NA	Sodium
B	Boron	NI	Nickel
BA	Barium	P	Phosphorus
BE	Beryllium	PB	Lead
BI	Bismuth	S	Sulfur
CA	Calcium	SB	Antimony
CD	Cadmium	SE	Selenium
CL	Chlorine	SI	Silicon
CO	Cobalt	SN	Tin
CR	Chromium	SR	Strontium
CU	Copper	TH	Thorium
FE	Iron	TI	Titanium
HG	Mercury	TL	Thallium
K	Potassium	U	Uranium
LI	Lithium	V	Vanadium
MG	Magnesium	ZN	Zinc

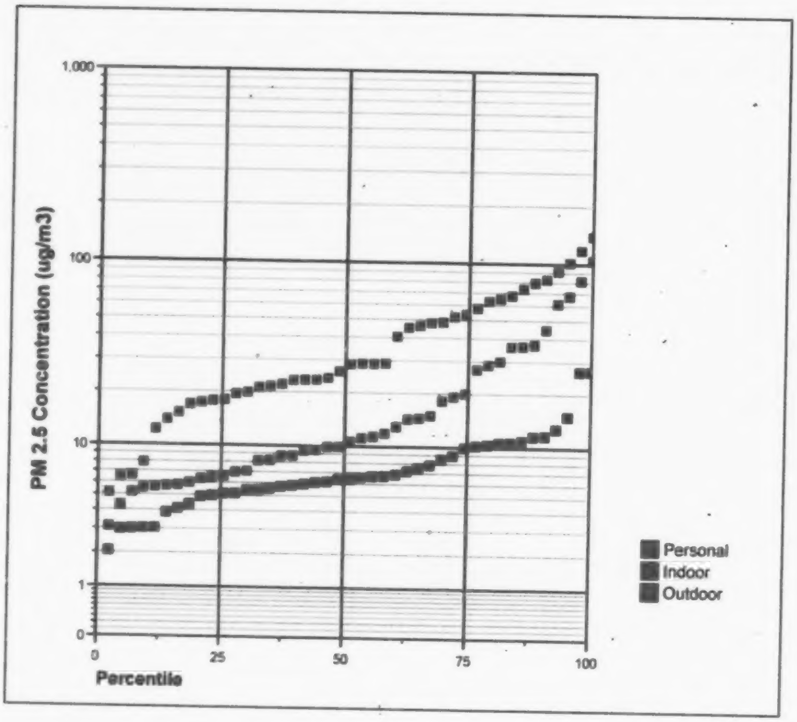
A total of 44 participants wore the particulate monitors or had them placed in their homes. Table 14 shows the distribution of the 162 particulate matter filters.

Table 14: Distribution of Particulate Matter ($PM_{2.5}$) Filters

Location	Totals
Personal	44
Indoor	44
Outdoor	60
Blank	14
Total	162

Figure 66 shows the cumulative distribution of $PM_{2.5}$ concentrations for the three types of samplers. The median and 95th percentile $PM_{2.5}$ levels for the different locations are summarized in Table 15 and compared to guidelines and levels in other communities. The $PM_{2.5}$ guideline is currently under review and will be replaced by a Canadian wide standard of 30µg/m^3 over a 24-hour period by 2010. The levels of outdoor $PM_{2.5}$ levels measured in Wabamun and surrounding area were similar to other communities in that they were well below guidelines. Median levels of indoor and personal $PM_{2.5}$ are higher than previous studies however it is difficult to draw firm conclusions from the completed analysis because of the limited sample size.

Figure 66: Distribution of $PM_{2.5}$



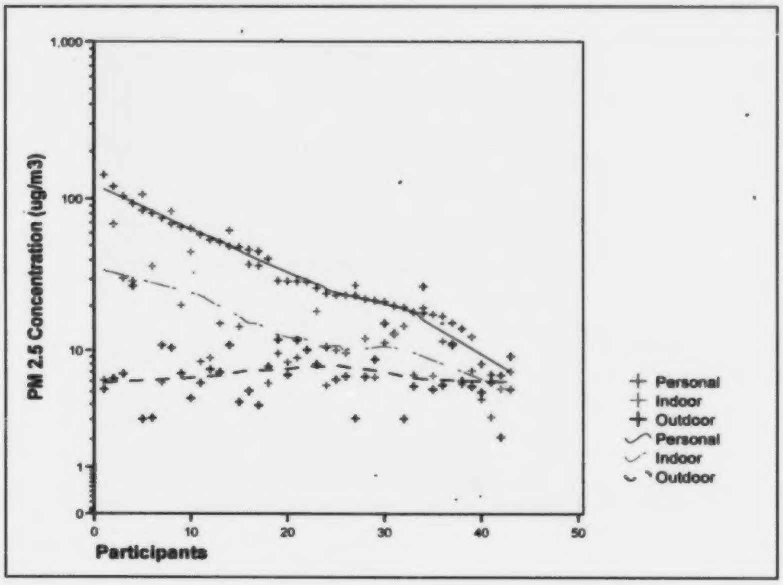
There were too few measurements to determine temporal trends. Figure 67 shows the personal exposure concentrations compared to average indoor and outdoor concentrations. There is a moderate correlation between personal and indoor concentrations, and no relationship to outdoor concentrations.

Table 15: Comparison of $PM_{2.5}$ Levels (µg/m³) with Guidelines and Other Studies[38,39,40]

Parameter	Personal	Indoor	Outdoor	Ambient Station	P/I ratio	P/O ratio	I/O ratio
Wabamun Median	28.7	10.7	6.5	N/A	2.7	4.4	1.6
Wabamun 95th	115.4	79.4	24.5	N/A	1.5	4.7	3.2
Fort Saskatchewan Median	15.1	6.98	6.56	N/A	2.2	2.3	1.06
Fort Saskatchewan 95th	187.9	24.3	13.18	N/A	7.7	14.2	1.8
Grande Prairie Median	19.9	8.7	4.4	N/A	2.3	4.6	2.0
Grande Prairie 95th	116.3	52.9	9.5	N/A	2.2	12.3	5.6
Fort McMurray Median	25	8.6	8.4	6.2	2.7	3.20	1.17
Fort McMurray 95th	88	3.5	23.2	13.3	2.6	4.88	1.88
Lethbridge Median	22.3	6.7	6.3	N/A	3.3	3.55	1.06
Lethbridge 95th	27.4	12.3	16.8	N/A	2.2	1.64	0.73
Relevant Studies	18.7[i]	15.4[i]	13.2[i]	9[ii]	1.21[i]	1.42[i]	1.17[i]
Guideline/Reference Level	N/A	100 (hour)[iii]	30 (24-hour)[iv]	15 (year) 65 (day) USEPA 30 (24-hour)[iv]	N/A	N/A	N/A

i: Pellizzari et al., 1999.
ii: Cheng et al., 1998.
iii: Health Canada, 1989.
iv: Canada wide-standard, 2010

Figure 67: Relationship between Exposures to $PM_{2.5}$ by Sampler Site



Further analysis involved the relative amounts of the analyzed metals found in the samples. The following figures (Figures 68 and 69) show the relative amounts of the various metals in the particulates samples. Figure 68 shows the average amounts of metal (in ng/m^3) across all sampler types. Figure 69 shows personal, indoor and outdoor concentrations of metals in $PM_{2.5}$ in the same order as shown in the previous graph.

Figure 68: Overall Concentration of Metals in Particulate

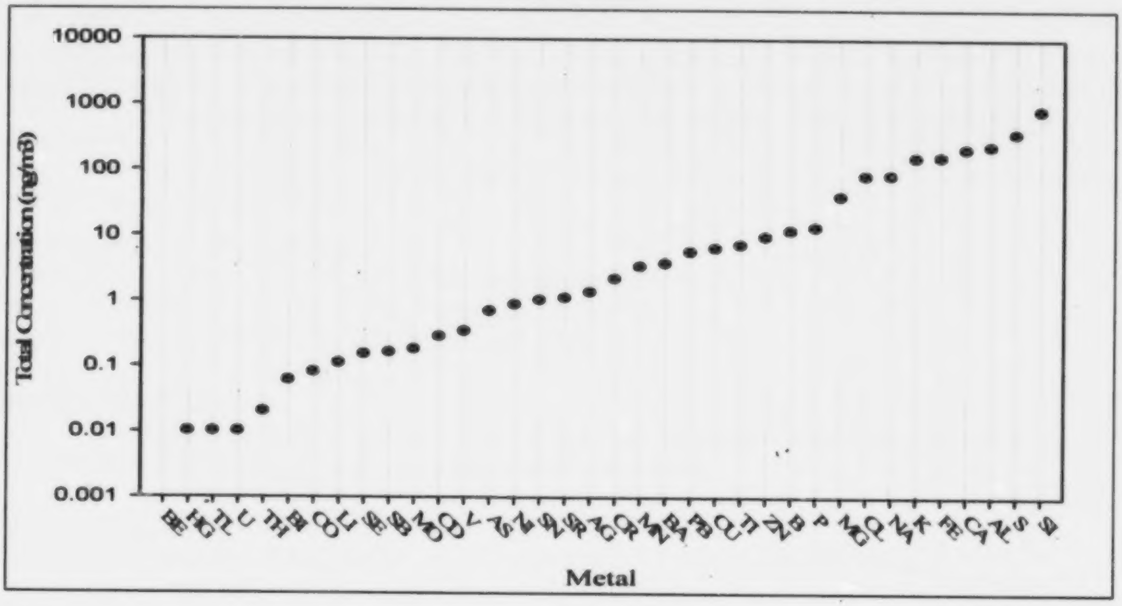
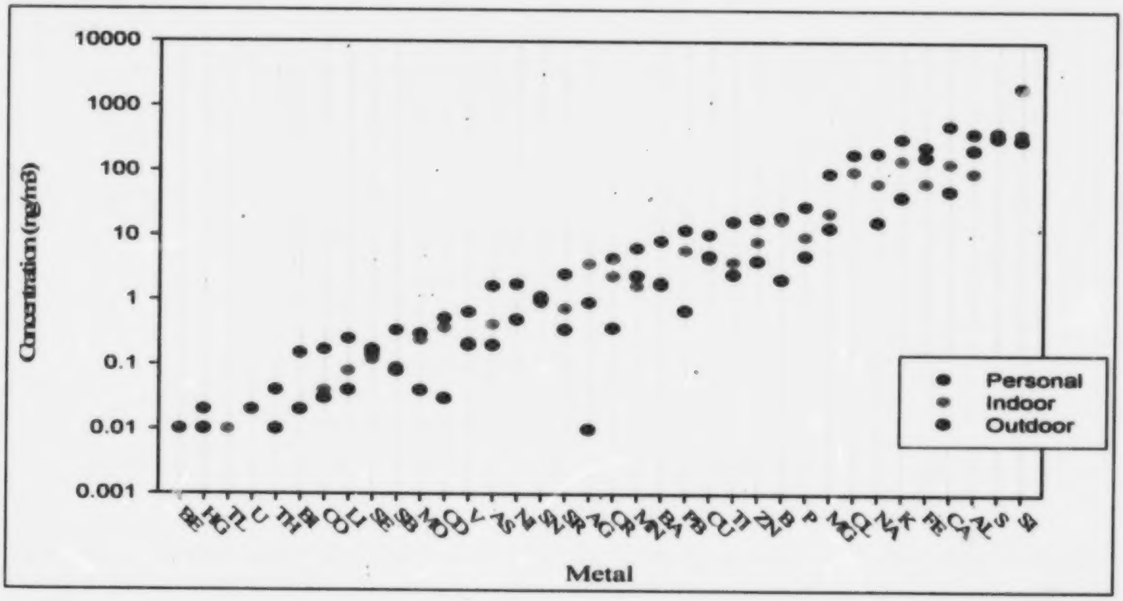


Figure 69: Concentration of Metals in $PM_{2.5}$



7.3 Polycyclic Aromatic Hydrocarbons (PAHs)

The PAH component of WACEHEAP is a combination of real time and integrated samples that enables an analysis of indoor, outdoor and area sources. There is significant statistical power in the real time data that provides minute to minute changes in PAH levels. The integrated weekly samples are much fewer in number but provide a more accurate measure of individual PAH compounds. The combination of the sampling techniques provides a good characterization of PAH exposure.

For WACEHEAP, the real time PAH data was not collected due to problems with the equipment. Without the real time data, the small number of integrated samples collected did not provide the statistical power necessary to make meaningful conclusions and as a result this analysis was not undertaken.

8.0 Exposure Relationships[3]

8.1 A General Model of Potential Relationships

The factors that determine the level of chemicals to which an individual is exposed are numerous, and often specific to the individual. The current analyses measured personal exposure levels integrated over one-week periods, and did not measure moment-to-moment concentration levels of the chemicals being monitored. This restricts the ability to provide definitive evidence of the exact causes of fluctuations in personal exposure levels. Nevertheless, a number of potential contributors to personal exposure levels were monitored and could be examined in the context of a general model of the potential causes of fluctuations in personal exposure levels. The statements below summarize some of the general expectations about relationships between exposure levels and other factors. The "→" symbol is used to postulate a causal relationship.

Concentration Interrelations:

Indoor concentration levels → Personal concentration levels
Outdoor concentration levels → Indoor concentration levels
Outdoor concentration levels→ Personal concentration levels

Activity Variations:

Fluctuations in Weekly Activity Pattern → Fluctuations in Personal concentration levels
Smoking Activity → Personal, Indoor concentration levels

Residence Characteristics:

Characteristics of the principal residence → Indoor, Personal concentration levels

For each of these potential relationships, variables were available. They are briefly described below, and a label is provided for use in interpreting the tables of results that follow. (Variables in brackets are reference categories against which other category members are compared).

Exposure:

pcon	Personal concentration levels
icon3	Indoor concentration levels
ocon3	Outdoor levels

Time-Activity:

ih	Proportion of time inside at home
oh	Proportion of time outside at home
iw	Proportion of time inside at work
ow	Proportion of time outside at work
ia	Proportion of time other indoor activities
oa	Proportion of time other outdoor activities
t	Proportion of time in motorized vehicle

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[3] This section previously published in The Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Methods Report, 2000.

Smoking:

smkhome	Indicates if smoking occurs in the home
smkcar	Indicates if smoking occurs in the vehicle
smkamt	Number of cigarettes smoked per day (divided by 10)
smkexp2	Hours per day exposed to cigarette smoke

Job Status:

jobft	Has a full time job
jobpt	Has a part time job

Garage

attg	Attached Garage
detg	Detached garage
(no garage)	No garage

Housing Characteristics:

new	Built from 2000 to present
med	Built between 1980 to 1999
old	Built prior to 1980
trailor	Mobile home
mult2	Multiple housing (apartment or townhouse)
(single)	Single family detached dwelling
unpaved	Unpaved driveway
nfcdair	Indicates heating other than forced air
caret	Indicates presence of a cold air return

Urban-Rural

urban	Located in urban centre (Stony Plain, Spruce Grove, or Devon)
rural	Located outside urban centre

Paul First Nation Resident

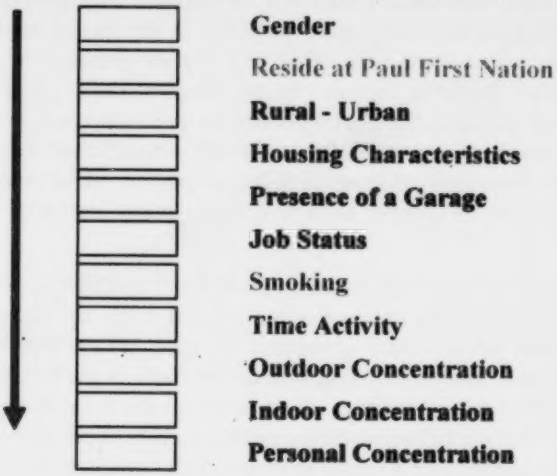
resident	Resident on Paul First Nation Reserve

Gender

gender	Female or Male

Further consideration of these variables and the hypothesized relationships led to the postulation of the following general recursive model to guide analysis and interpretation (Figure 70).

Figure 70: A General Ordering of Factors Influencing Personal Exposure



Gender
Reside at Paul First Nation
Rural - Urban
Housing Characteristics
Presence of a Garage
Job Status
Smoking
Time Activity
Outdoor Concentration
Indoor Concentration
Personal Concentration

A recursive ordering, such as this, is intended to capture a causal ordering among sets of variables. Specifically, as a hypothesis, it suggests that variables earlier (or higher) in the chain can have a causal effect on variables later (or lower) in the chain, but not vice versa. In addition, no reciprocal causal relations are postulated. Finally, for variables within a set, no causal ordering or priority is postulated.

There are various intuitive relationships that are captured by this ordering such as the notion that gender will influence job status, that job status will influence time and activity patterns, and that indoor concentrations will influence personal concentrations. There are a number of relationships that might be taken to be implied by the model which are not specifically intended; and which in a more detailed model could be explicitly left out (i.e. placing housing characteristics ahead of smoking characteristics in the model). There are also some relationships that may be excluded by this ordering which might nevertheless appear to under some circumstances. For example, it may be postulated that indoor concentrations might have an effect on outdoor concentrations rather than the reverse. In the current model, outdoor concentrations were placed ahead of indoor concentrations because the major source of concern for exposure is the possibility that an external source leads to high indoor concentrations.

This recursive ordering was used as a heuristic device to structure the specific analyses of the concentrations of the individual chemicals. The data are blind to this ordering, and alternate hypotheses could be examined either by independent analysts or as a later follow-up to the current analyses. What the heuristic model does allow is a hypothetical partitioning of causal influence between total and direct effects within the model. Direct effects refer to the strength of relationships directly between an independent variable or variable set and a dependent variable, while total effects include relationships between the independent variables or variable sets and the dependent variables that include other independent variables as mediators of the influence. For example, 'having a full time job' might have a total effect on 'personal exposure to octane', even though the causal force might be carried by a relationship between 'having a full time job' and 'amount of time travelling in a car' and by a relationship 'amount of time travelling in a car' and 'personal exposure to octane'. It should be noted that in the model presented in Figure 70, there are a large number of ways in which a variable group or factor may have an indirect effect on personal exposure levels.

8.2 Methods of Analysis

Regression analysis was used for each contaminant to quantify the amount of the variability in personal exposure that could be attributed to variability in each factor. The traditional measure used for this purpose is a proportion of variance, R^2, derived from the correlation, r, or multiple correlations, R, of the variable(s) to personal levels when the effects of including other variables in the model are taken into account. The measure R^2 will vary from 0.0 when there is no effect to 1.0 when personal levels can be perfectly predicted by variation in some other factor or factors. In the simplest case, where only two variables are being considered, a scatterplot of these two variables can be presented which shows the degree of relationship between them. It is usually accompanied by a correlation coefficient that quantifies the strength of that relationship and, which when squared represents the proportion of variance measure (R^2). Unfortunately, simple scatterplots are not available as a tool when many variables are being simultaneously considered.

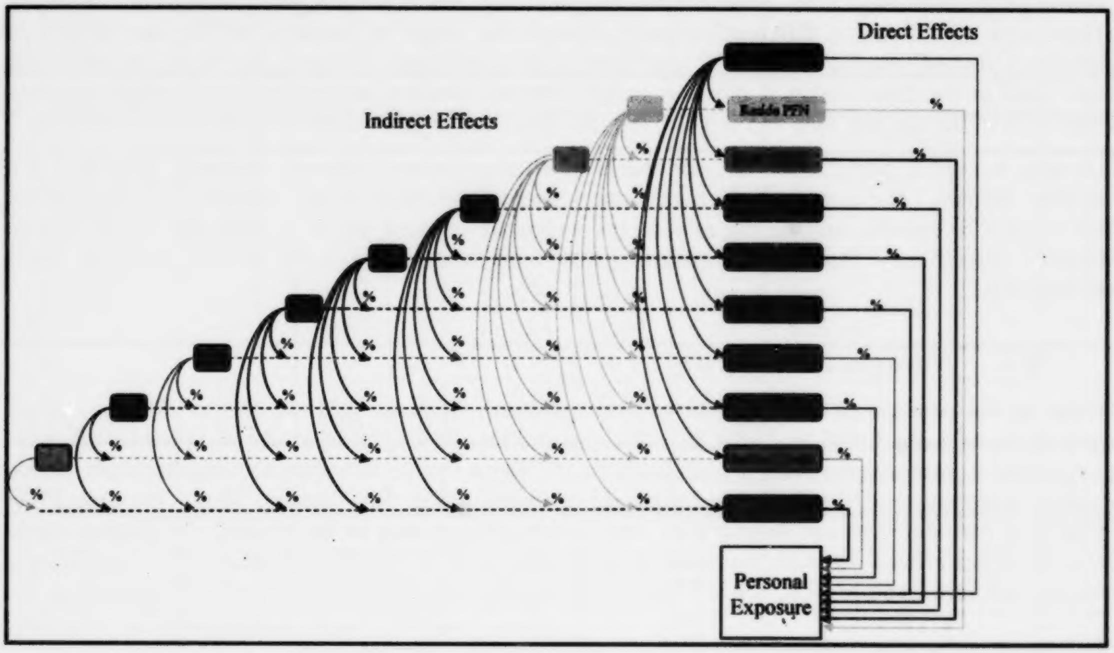
In general, the analysis of each contaminant proceeded as follows: a hierarchical set regression analysis[41] was performed in which variables were entered into the regression equation by set in the order specified by the recursive ordering and intermediate results were generated to give information about the relationships between variable sets. This form of analysis closely follows the logic of the recursive model in Figure 70. It can identify variables which have an indirect effect upon personal exposure levels by effecting changes in other variable sets intermediate between them and personal exposure in the recursive ordering. Such a multi-step procedure is necessary since a single analysis of all variables will obscure the intermediate relationships. In addition, since the concentration of exposures was typically positively skewed, in all cases, a generalized linear model was used in which the concentrations were assumed to follow a log normal distribution.

All analyses of passive samplers were conducted on 172 Wabamun and area residents for whom complete data were available.

8.3 Presentation of Results

Comparing the effect of many factors simultaneously on personal exposure can become very complex, not only because of the increased number of factors but also because of the numerous potential pathways between the factors. Communicating the results can also be difficult if the goal is to describe effects due to each factor (direct effects) as well as the numerous interrelationships between the factors (indirect effects) that may be noteworthy. In an effort to communicate these results clearly, a pictorial description of the general model used in this analysis was developed and is presented in Figure 71. The figure, which is an extension of the recursive model presented in Figure 70, shows the factor groups in coloured boxes interconnected with black arrows to the box representing personal exposure. A coloured arrow connecting the factor and personal exposure on the right side of the figure represents the potential direct effect of each factor group on personal exposure. The potential indirect effects of each factor on personal exposure acting through the subsequent factors are shown by the cascading coloured arrows on the left of the figure. The arrows are colour coded to represent the factor groups. In subsequent sections of this report when this model is displayed for a contaminant only the largest effects and factor groups are displayed. The magnitude of the effect is written beside the arrow as a percentage and is reflected in the size of the arrow. The summations of the percentages on the figures will roughly total the variation in personal exposure described by the model and that is also noted on the figure.

Figure 71: General Model of Personal Exposure Used to Investigate Direct and Indirect Effects

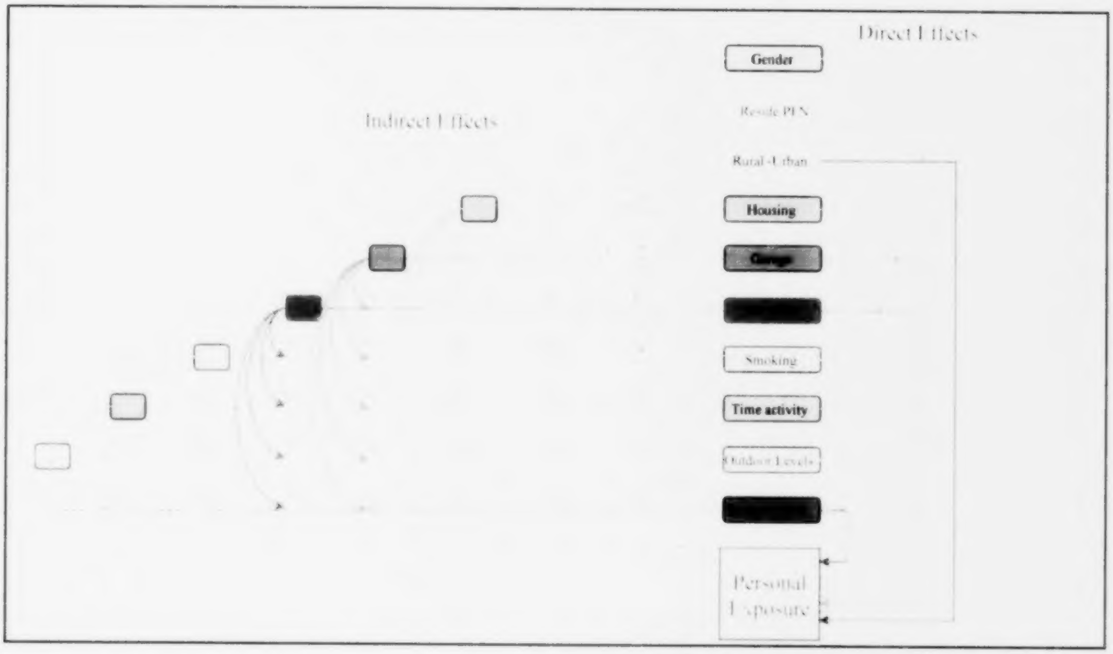


In addition to figures such as Figure 71 that are presented for a selection of the contaminant models, two tables present the results of the hierarchical set regression conducted on each contaminant and provide the information required to construct the summary figure.

The first table presents comparative multiple correlation coefficients (Rs) derived from the hierarchical set analysis. The second column shows the total effect of the variable set in a regression analysis of personal exposure on this set of variables alone. The third column shows the total effect of the variable set with all variable sets higher in the causal ordering already entered into the regression. A decrease in the values from the second to the third column indicates that the variable sets higher in the recursive ordering had an effect on the variable set under consideration. Conversely, small differences suggest that a variable set is independent of those higher in the recursive ordering. The fourth column indicates the effect of a variable set (called the semi-partial R) with all other variable sets already in the regression. It indicates the direct effects of the variable set. If there is a decrease in the fourth column from the third column, this indicates that a variable set influences a variable set lower in the recursive ordering (and hence has an indirect effect). Small values in all columns indicate small effects. Though a detailed examination of confidence intervals was not performed, in general, multiple correlation coefficients in excess of 0.20 are likely to differ significantly from 0.0 and indicate a real effect. Clearly, the validity of this table depends upon the validity of the chosen recursive ordering, and alternative orderings would change the values in the second column (and likely the ordering of the table which follows the recursive ordering) as well.

The square of the fourth column of this table (multiplied by 100) represents the percentage of the variation in personal exposure accounted for directly by a particular factor as presented on the right side of the summary figure. The total indirect effects (from which the figures on the left of the summary figure are derived) are obtained by subtracting this figure from the square of the value in the second column.

Figure 71: General Model of Personal Exposure Used to Investigate Direct and Indirect Effects



In addition to figures such as Figure 71 that are presented for a selection of the contaminant models, two tables present the results of the hierarchical set regression conducted on each contaminant and provide the information required to construct the summary figure.

The first table presents comparative multiple correlation coefficients (Rs) derived from the hierarchical set analysis. The second column shows the total effect of the variable set in a regression analysis of personal exposure on this set of variables alone. The third column shows the total effect of the variable set with all variable sets higher in the causal ordering already entered into the regression. A decrease in the values from the second to the third column indicates that the variable sets higher in the recursive ordering had an effect on the variable set under consideration. Conversely, small differences suggest that a variable set is independent of those higher in the recursive ordering. The fourth column indicates the effect of a variable set (called the semi-partial R) with all other variable sets already in the regression. It indicates the direct effects of the variable set. If there is a decrease in the fourth column from the third column, this indicates that a variable set influences a variable set lower in the recursive ordering (and hence has an indirect effect). Small values in all columns indicate small effects. Though a detailed examination of confidence intervals was not performed, in general, multiple correlation coefficients in excess of 0.20 are likely to differ significantly from 0.0 and indicate a real effect. Clearly, the validity of this table depends upon the validity of the chosen recursive ordering, and alternative orderings would change the values in the second column (and likely the ordering of the table which follows the recursive ordering) as well.

The square of the fourth column of this table (multiplied by 100) represents the percentage of the variation in personal exposure accounted for directly by a particular factor as presented on the right side of the summary figure. The total indirect effects (from which the figures on the left of the summary figure are derived) are obtained by subtracting this figure from the square of the value in the second column.

The second table reports the β weights and multiple correlation coefficients for each variable from each variable set for each stage in the recursive ordering analysis. The β weights give a method of comparing relative size of effects of different variables, though the range of variation within the sample of individuals studied, especially if small, may need to be considered in interpreting these weights. The main value of the table is that it provides insight into the relative importance of individual variables within each of the variable sets, and can also suggest direct and indirect effects for individual variables.

This table is used to partition the indirect effects of a factor between alternate pathways presented in a summary diagram. The changes in the sum of the squared coefficients for the variables in a single group from column to column indicate the relative proportion of variance due to a particular set of indirect pathways (specifically that indirect pathway that is present in only one of the columns under consideration).

8.4 Nitrogen Dioxide (NO_2)

Results of the analysis of relationships between personal exposures and the factors that may affect exposure to NO_2 are found in Table 16. The second column of the table shows individual factors' relationships to personal exposure if considered alone. These are the R^2 values that resulted from simple bivariate scatterplots of the factor and personal exposure. The third column shows the amount of variation in personal exposure described by each factor in the context of the model. The fourth column shows the direct effects. Overall, the model accounted for about 57% (48% adjusted) of the variability in personal exposure levels to NO_2. Table 17 shows the results of the regressions done for the modeling.

Table 16: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.08	0.08	0.09
Resident of PFN	0.12	0.08	0.10
Urban	0.06	0.00	0.05
Housing Characteristics	0.26	0.25	0.10
Garage	0.06	0.10	0.08
Job Status	0.05	0.00	0.03
Smoking Characteristics	0.17	0.19	0.17
Time Activity	0.32	0.34	0.26
Outdoor Concentration	0.29	0.23	0.09
Indoor Concentration	0.63	0.53	0.53

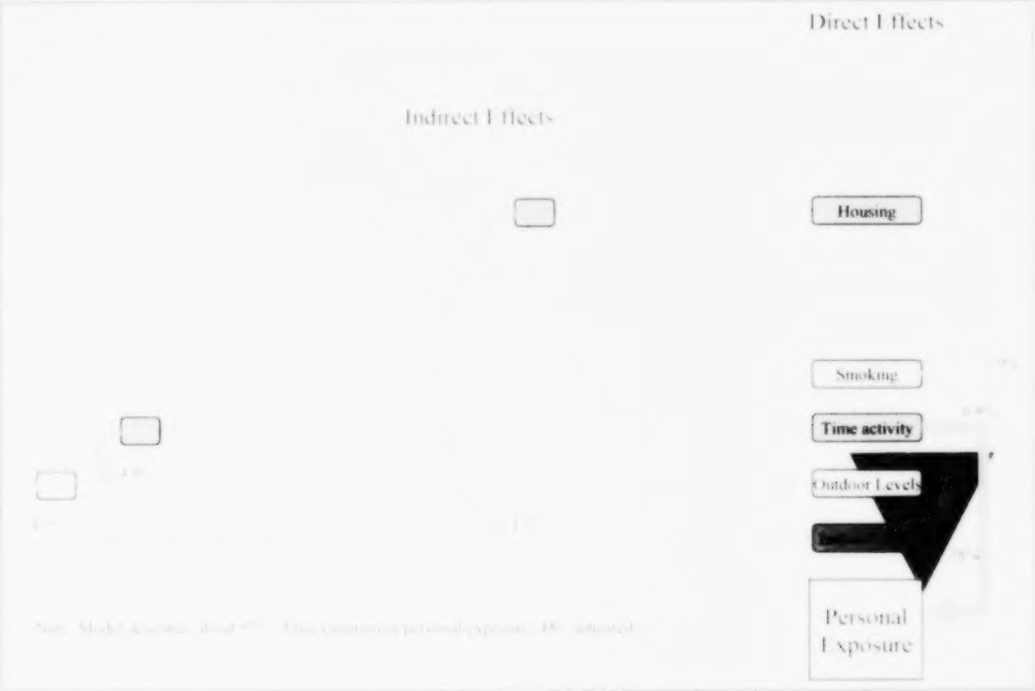
Note: PFN = Paul First Nation

Table 17: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	-0.10	-0.03	-0.01	-0.11	-0.08	-0.08	-0.08	-0.08	-0.08	-0.09
Resident of PFN	-0.21	-0.12	-0.20	-0.15	-0.12	-0.12	-0.06	-0.07	-0.08	
URBAN	-0.08	-0.12	-0.06	-0.01	-0.01	-0.01	-0.02	0.02		
TRAILOR	-0.04	-0.26	-0.26	-0.25	-0.24	-0.24	-0.22			
MULT2	0.08	0.12	0.09	-0.09	0.10	0.10	0.11			
MED	-0.03	-0.06	-0.05	-0.08	-0.09	-0.09	-0.07			
OLD	-0.08	-0.06	-0.04	-0.11	-0.09	-0.09	-0.06			
NFCDAIR	-0.03	-0.04	-0.02	-0.04	-0.05	0.05	-0.05			
CARET	-0.05	-0.01	0.02	0.04	0.04	0.03	0.02			
ATTG	-0.11	-0.07	-0.10	-0.15	-0.14	-0.15				
DETG	-0.05	-0.00	-0.04	-0.07	-0.07	-0.07				
UNPAVED	0.04	0.03	-0.03	-0.01	0.01	-0.02				
JOBFT	-0.04	-0.13	-0.14	-0.02	-0.01					
JOBPT	-0.03	-0.09	-0.09	-0.02	-0.02					
SMKHOME	0.18	0.30	0.27	0.22						
SMKCAR	-0.08	-0.20	-0.14	-0.10						
SMKAMT	0.05	0.04	0.03	-0.01						
SMKEXP2	0.08	0.04	0.04	0.08						
IH	0.09	0.03	0.05							
OH	-0.16	-0.18	-0.28							
IW	0.21	0.19	0.20							
OW	0.01	0.07	0.02							
IA	0.13	0.06	0.06							
OA	-0.05	-0.04	-0.04							
T	0.07	0.15	0.15							
OCON3	0.12	0.30								
ICON3	0.62									
R	0.76	0.54	0.49	0.35	0.30	0.30	0.28	0.12	0.12	0.09

The modeling results in Tables 16 and 17 were combined and have been represented pictorially in Figure 72. Only direct effects with R^2 values greater than 0.02 (i.e., 2%) are displayed while indirect effects of R^2 greater than 2.5% are displayed.

Figure 72: Results of Model of Personal Exposure to Nitrogen Dioxide



The major effects on personal exposure levels to NO_2 identified by this exposure model were:

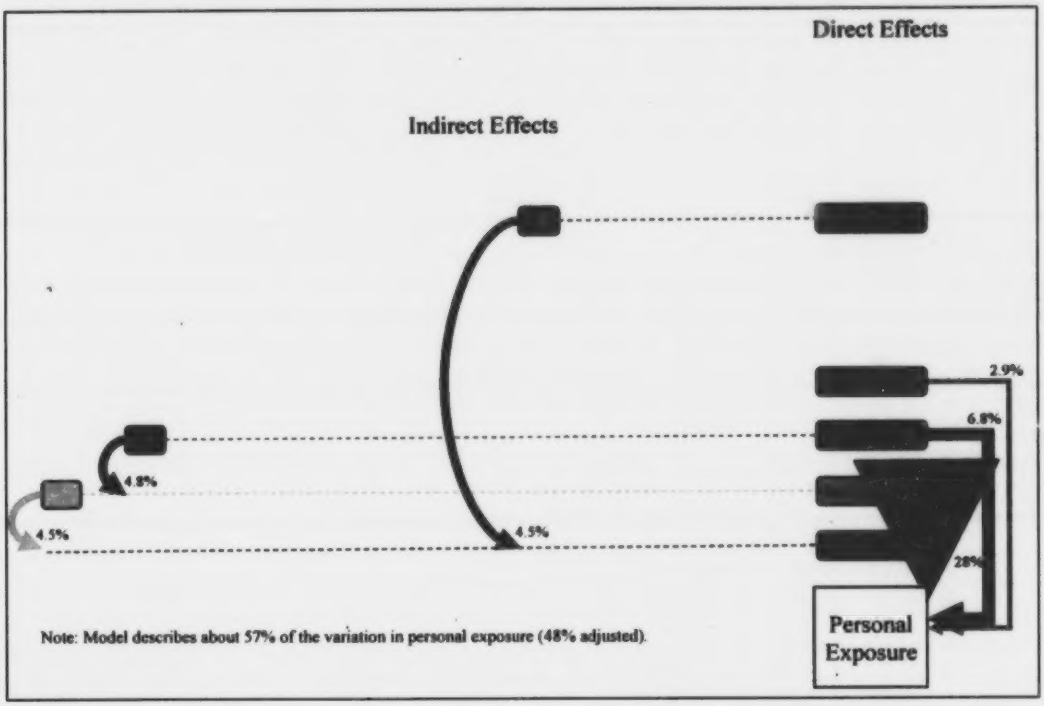
- ***Indoor levels***, directly (28.0%)
- ***Time Activity***, directly (6.8%)
- ***Time Activity***, operating indirectly through outdoor levels (4.8%)
- ***Housing***, operating indirectly through indoor levels (4.5%)
- ***Outdoor levels***, operating indirectly through indoor levels (4.5%)
- ***Smoking***, directly (2.9%)

Overall, indoor variation accounted for roughly one-half of the variation in personal exposure described by the model. Time activity was also an important driver of personal exposure while smoking and housing had more minor effects.

These results are similar to other CEHEAP communities except that there is not a significant rural-urban effect which is likely due to the fact that there was not a large community within the program boundary.

The modeling results in Tables 16 and 17 were combined and have been represented pictorially in Figure 72. Only direct effects with R^2 values greater than 0.02 (i.e., 2%) are displayed while indirect effects of R^2 greater than 2.5% are displayed.

Figure 72: Results of Model of Personal Exposure to Nitrogen Dioxide



Note: Model describes about 57% of the variation in personal exposure (48% adjusted).

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These results are similar to other CEHEAP communities except that there is not a significant rural-urban effect which is likely due to the fact that there was not a large community within the program boundary.

8.5 Sulfur Dioxide (SO_2)

Results of the analysis of relationships between personal exposures and the factors that may affect exposure to SO_2 are found in Table 18 and 19. The second column of the table shows the relationship between individual factors and personal exposure if considered alone. These are the R^2 values that resulted from simple bivariate scatterplots of the factor and personal exposure. The third column shows the amount of variation in personal exposure described by each factor in the context of the model. The fourth column shows just the direct effects. The model accounted for about 34% (22% adjusted) of the variation in personal exposure to SO_2.

Table 18: Comparative Multiple Regression Coefficients for Variable Sets

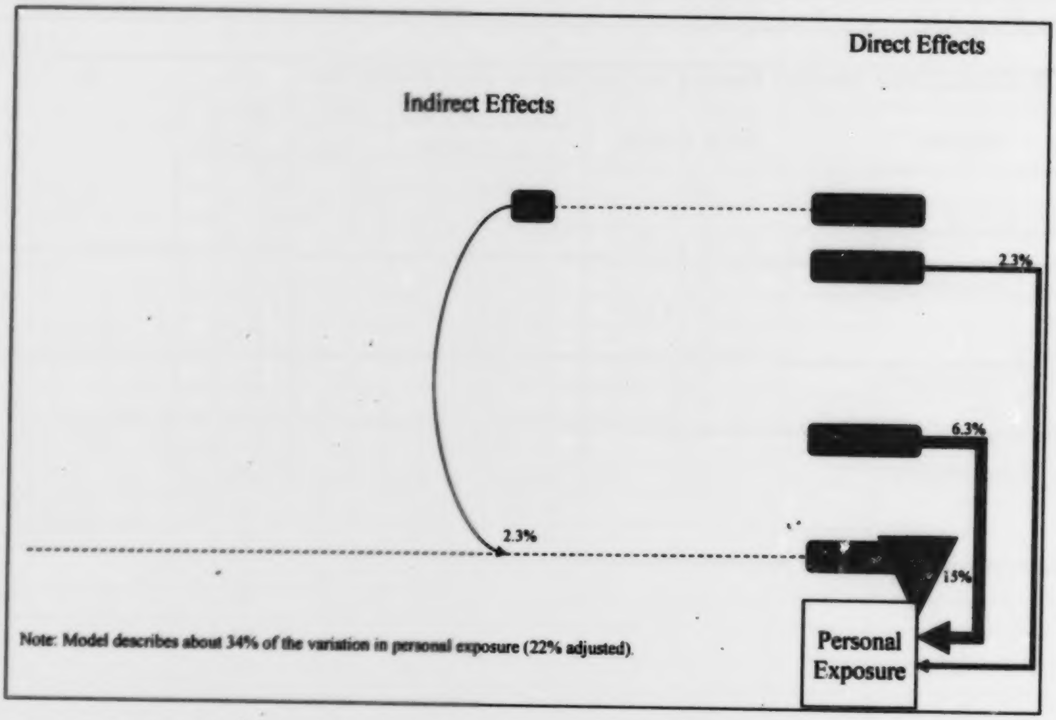
Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.06	0.06	0.04
Resident of PFN	0.07	0.00	0.04
Urban	0.05	0.04	0.03
Housing Characteristics	0.21	0.22	0.10
Garage	0.22	0.20	0.15
Job Status	0.06	0.08	0.05
Smoking Characteristics	0.07	0.04	0.06
Time Activity	0.33	0.28	0.25
Outdoor Concentration	0.14	0.10	0.09

Table 19: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	-0.06	-0.08	-0.09	0.02	0.03	0.02	0.03	0.07	0.06	0.07
Resident of PFN	-0.09	0.11	0.13	0.19	0.18	0.16	0.01	-0.01	0.02	
URBAN	0.04	0.06	0.02	-0.06	-0.05	-0.06	-0.11	-0.06		
TRAILOR	0.04	0.04	0.02	-0.02	-0.01	-0.01	-0.06			
MULT2	-0.00	0.02	0.02	0.01	0.01	0.02	-0.02			
MED	0.03	-0.04	-0.05	-0.05	-0.05	-0.06	-0.08			
OLD	-0.08	-0.17	-0.17	-0.18	-0.17	-0.18	-0.19			
NFCDAIR	0.01	0.01	-0.00	-0.00	-0.00	-0.01	-0.04			
CARET	0.07	0.10	0.11	0.10	0.11	0.10	0.15			
ATTG	0.17	0.25	0.23	0.26	0.27	0.26				
DETG	0.20	0.22	0.20	0.21	0.22	0.21				
UNPAVED	0.10	0.14	0.15	0.15	0.15	0.14				
JOBFT	0.01	-0.03	-0.05	-0.07	-0.07					
JOBPT	0.06	-0.02	-0.03	-0.07	-0.07					
SMKHOME	-0.08	0.02	0.02	0.05						
SMKCAR	0.05	-0.03	-0.01	-0.02						
SMKAMT	0.05	0.04	0.01	-0.04						
SMKEXP2	0.03	0.01	-0.00	0.01						
IH	-0.04	-0.02	-0.02							
OH	0.22	0.24	0.23							
IW	-0.07	-0.05	-0.05							
OW	0.09	0.11	0.14							
IA	-0.04	-0.07	-0.08							
OA	0.07	0.06	0.06							
T	0.13	0.17	0.18							
OCON3	0.11	0.13								
ICON3	0.46									
R	0.60	0.45	0.43	0.33	0.32	0.31	0.24	0.08	0.07	0.07

The modeling results in Tables 18 and 19 were combined and have been represented pictorially in Figure 73. Only direct and indirect effects with R^2 values greater than 0.02 (i.e., 2%) are displayed.

Figure 73: Results of Model of Personal Exposure to Sulfur Dioxide



Note: Model describes about 34% of the variation in personal exposure (22% adjusted).

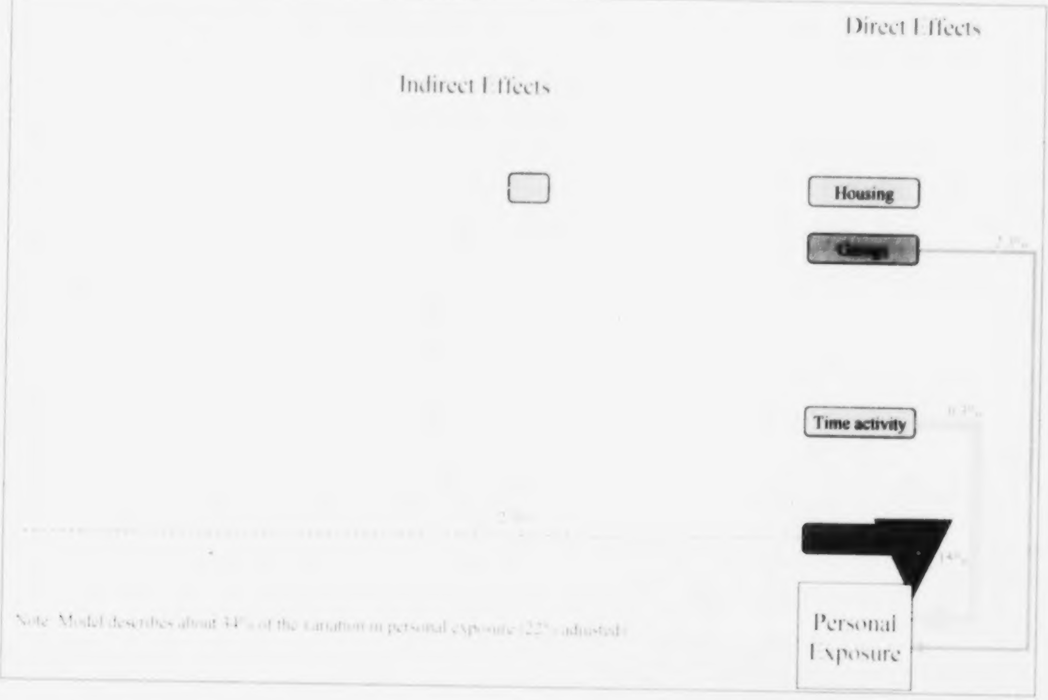
A qualitative estimate of the pathways of the indirect effects has been made. The major effects identified in the analysis were as follows:

- ***Indoor levels,*** directly (15.2%)
- ***Time Activity,*** directly (6.3%)
- ***Housing,*** operating indirectly apparently through effects on indoor levels (2.3%)
- ***Garage,*** directly (2.3%)

Overall, variations in indoor levels accounted for almost half the variation in personal exposure. In addition, the age of the participant's housing affects the personal exposure by affecting indoor levels. SO_2 exposure was directly affected by time activity specifically when time was spent outdoors at work. Having an attached garage was also an important variable directly affecting SO_2 exposure.

The modeling results in Tables 18 and 19 were combined and have been represented pictorially in Figure 73. Only direct and indirect effects with R^2 values greater than 0.02 (i.e., 2%) are displayed.

Figure 73: Results of Model of Personal Exposure to Sulfur Dioxide



Note: Model describes about 34% of the variation in personal exposure (22% adjusted)

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- ***Garage,*** directly (2.3%)

Overall, variations in indoor levels accounted for almost half the variation in personal exposure. In addition, the age of the participant's housing affects the personal exposure by affecting indoor levels. SO_2 exposure was directly affected by time activity specifically when time was spent outdoors at work. Having an attached garage was also an important variable directly affecting SO_2 exposure.

8.6 Ozone (O_3)

The results of the analysis comparing effects of factors on personal O_3 exposure are shown in Tables 20 and 21 and pictorially in Figure 74. The model accounted for about 72% (67% adjusted) of the variation in personal exposure.

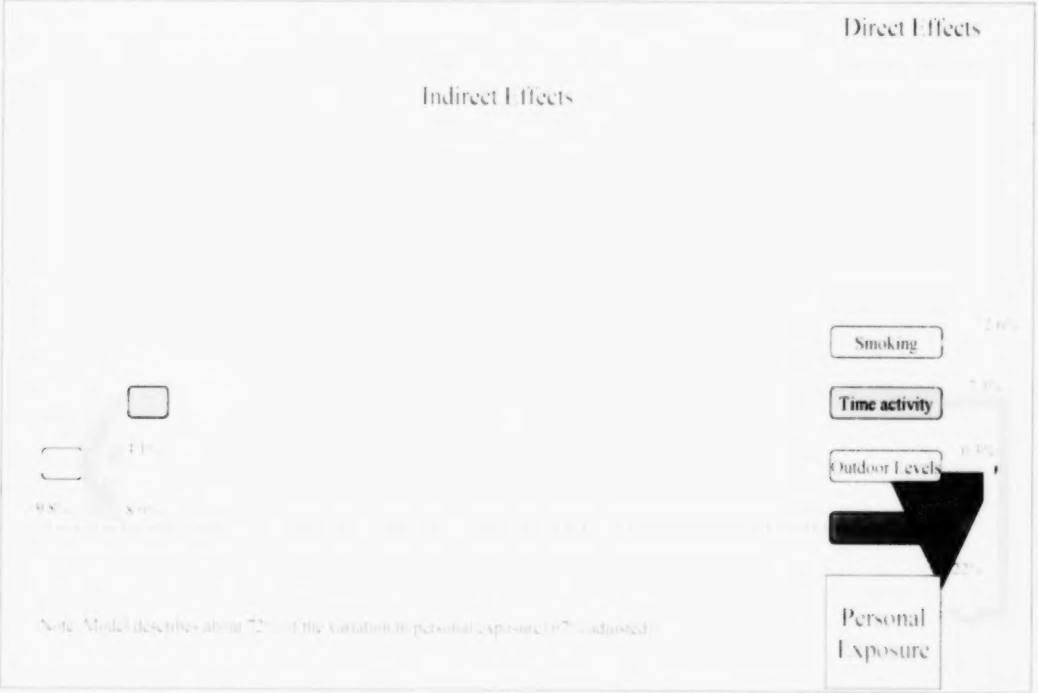
Table 20: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.05	0.05	0.03
Resident at PFN	0.18	0.17	0.04
Urban	0.10	0.00	0.08
Housing Characteristics	0.23	0.19	0.09
Garage	0.28	0.19	0.10
Job Status	0.05	0.06	0.10
Smoking Characteristics	0.25	0.17	0.16
Time Activity	0.45	0.45	0.27
Outdoor Concentration	0.46	0.40	0.25
Indoor Concentration	0.72	0.47	0.47

Table 21: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	-0.04	-0.10	-0.13	0.05	0.07	0.06	0.06	0.06	0.06	0.05
Resident of PFN	0.10	0.18	0.10	0.13	0.02	-0.00	-0.15	-0.17	-0.17	
URBAN	0.12	0.16	0.13	-0.00	0.02	0.01	-0.02	0.00		
TRAILOR	-0.05	-0.09	-0.10	-0.14	-0.14	-0.14	-0.18			
MULT2	-0.05	-0.02	0.03	0.02	0.02	0.03	-0.00			
MED	0.06	0.06	0.00	0.01	0.02	0.01	-0.05			
OLD	-0.01	-0.06	-0.09	-0.05	-0.04	-0.05	0.01			
NFCDAIR	0.02	-0.04	0.02	0.02	0.05	0.04	0.04			
CARET	-0.02	0.00	0.00	-0.01	0.01	-0.00				
ATTG	0.15	0.19	0.20	0.25	0.24	0.23				
DETG	0.09	0.13	0.22	0.23	0.24	0.23				
UNPAVED	0.07	0.11	0.12	0.11	0.12	0.12				
JOBFT	0.08	0.08	0.00	-0.05	-0.07					
JOBPT	0.12	0.15	0.06	-0.02	-0.04					
SMKHOME	-0.10	-0.15	-0.04	0.00						
SMKCAR	-0.02	-0.02	-0.05	-0.09						
SMKAMT	-0.09	-0.12	-0.12	-0.16						
SMKEXP2	0.16	0.21	0.08	0.08						
IH	0.03	-0.09	-0.09							
OH	0.28	0.38	0.43							
IW	-0.05	-0.13	-0.12							
OW	0.09	0.14	0.15							
IA	0.04	-0.03	-0.04							
OA	0.10	0.11	0.13							
T	0.04	0.03	0.12							
OCON3	0.30	0.47								
ICON3	0.54									
R	0.85	0.71	0.59	0.37	0.33	0.32	0.26	0.18	0.18	0.05

Figure 74: Results of Model of Personal Exposure to Ozone



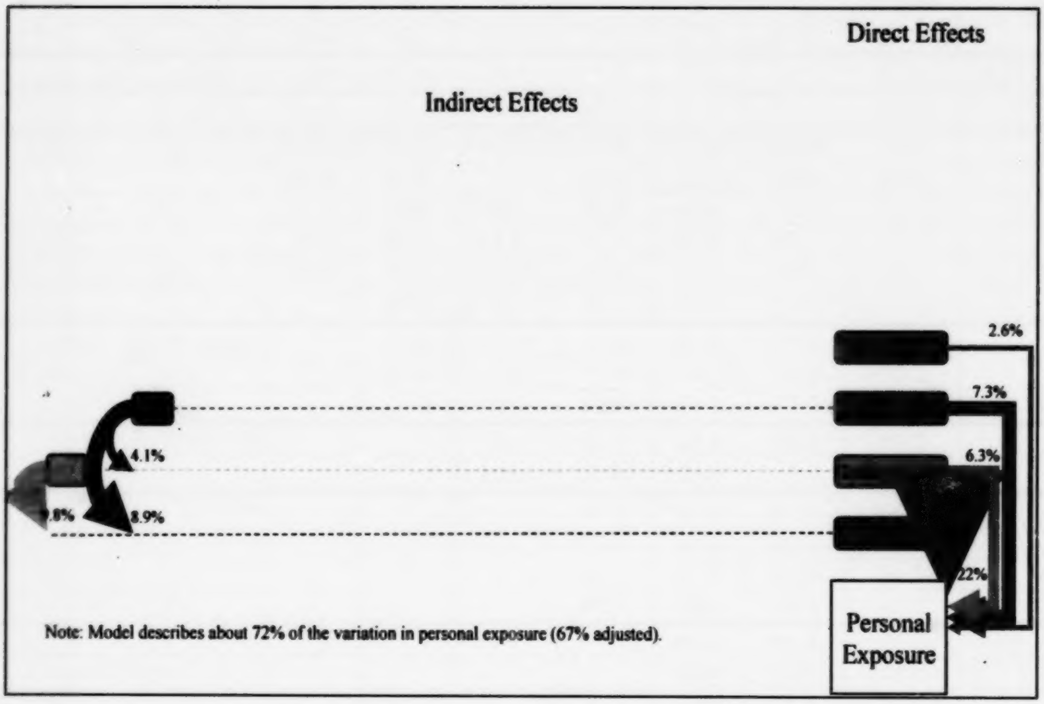
Note: Model describes about 72% of the variation in personal exposure (67% adjusted).

The model predicted about 72% of the variation (67% adjusted) in personal O_3 exposure across individuals and days. Important factors influencing variations in O_3 exposures were as follows:

- ***Indoor levels,*** directly (22.1%)
- ***Outdoor levels,*** operating indirectly through indoor air (9.8%)
- ***Time Activity,*** operating indirectly through effects on indoor air (8.9%)
- ***Time Activity,*** directly (7.3%)
- ***Outdoor levels,*** directly (6.3%)
- ***Time Activity,*** operating indirectly through effects on outdoor air (4.1%)
- ***Smoking,*** directly (2.6%)

The variation in personal exposure described by the model was mostly due to indoor levels directly and time activity and outdoor levels acting through indoor levels indirectly. Time activity patterns were an important variable predicting exposure with the most important time factor as how much time was spent outdoors. The direct effect noted from smoking may be due to additional time spent outdoors.

Figure 74: Results of Model of Personal Exposure to Ozone



Note: Model describes about 72% of the variation in personal exposure (67% adjusted).

The model predicted about 72% of the variation (67% adjusted) in personal O_3 exposure across individuals and days. Important factors influencing variations in O_3 exposures were as follows:

- ***Indoor levels,*** directly (22.1%)
- ***Outdoor levels,*** operating indirectly through indoor air (9.8%)
- ***Time Activity,*** operating indirectly through effects on indoor air (8.9%)
- ***Time Activity,*** directly (7.3%)
- ***Outdoor levels,*** directly (6.3%)
- ***Time Activity,*** operating indirectly through effects on outdoor air (4.1%)
- ***Smoking,*** directly (2.6%)

The variation in personal exposure described by the model was mostly due to indoor levels directly and time activity and outdoor levels acting through indoor levels indirectly. Time activity patterns were an important variable predicting exposure with the most important time factor as how much time was spent outdoors. The direct effect noted from smoking may be due to additional time spent outdoors.

8.7 Volatile Organic Compounds

The results of the investigation into the volatile organic compounds (VOCs) are presented as a group. Tables 22 to 47 show the modeled results for all the VOCs investigated. Figures 75 to 87 show pictorial representations of the exposure model results for these compounds.

All the VOC compounds investigated in this program except nonane demonstrate a pattern of exposure which shows the variation in indoor air levels dominates personal exposure and accounts for at least half of the variation explained by the model. Exposure to nonane was directly affected by being a Paul First Nation resident operating through indoor levels to affect personal exposure.

Decane, methylhexane, nonane, *N*-propylbenzene, and toluene showed exposure indirectly influenced by being Paul First Nation resident by impacting indoor levels. *M,-p*-xylene, heptane, ethylbenzene, decane, *o*-xylene showed personal exposure was affected by outdoor levels acting through indoor levels.

Contact with tobacco smoke and having an attached garage were also important factors associated with personal exposure to some of the VOCs. It should be emphasized that all of these factors are minor in comparison to indoor concentration levels.

Benzene

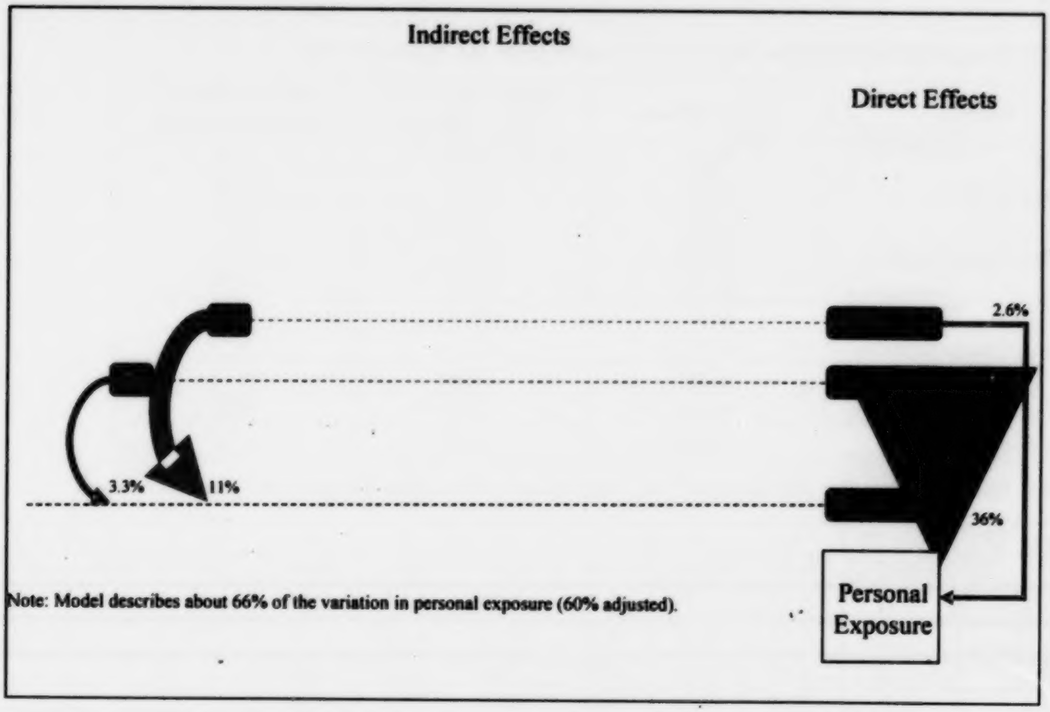
Table 22: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.09	0.09	0.03
Resident of PFN	0.14	0.1	0.10
Urban	0.20	0.17	0.08
Housing Characteristics	0.15	0.12	0.06
Garage	0.18	0.14	0.10
Job Status	0.13	0.12	0.08
Smoking Characteristics	0.39	0.38	0.16
Time Activity	0.22	0.23	0.14
Outdoor Concentration	0.03	0.84	0.04
Indoor Concentration	0.77	0.60	0.60

Table 23: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.05	0.09	0.10	0.04	0.09	0.08	0.08	0.10	0.08	0.93
Resident of PFN	-0.21	-0.16	-0.17	-0.19	0.01	0.03	-0.05	-0.02	0.10	
URBAN	-0.12	-0.23	-0.22	-0.18	-0.21	-0.22	-0.23	-0.21		
TRAILOR	-0.05	-0.07	-0.06	-0.05	-0.04	-0.02	-0.06			
MULT2	0.00	0.00	-0.00	0.01	0.02	0.02	0.01			
MED	-0.02	-0.02	-0.02	-0.02	-0.05	-0.04	-0.07			
OLD	-0.06	-0.06	-0.06	-0.10	-0.09	-0.08	-0.14			
NFCDAIR	-0.02	0.07	0.06	0.04	0.04	-0.01	-0.01			
CARET	-0.03	-0.04	-0.04	-0.02	-0.04	-0.04	-0.01			
ATTG	-0.10	0.22	0.19	0.16	0.19	0.20				
DETG	0.05	0.08	0.07	0.03	0.05	0.06				
UNPAVED	0.01	0.07	0.07	0.09	0.07	0.07				
JOBFT	-0.01	-0.01	-0.00	-0.06	-0.01					
JOBPT	-0.08	-0.16	-0.16	-0.17	-0.13					
SMKHOME	0.05	0.30	0.31	0.30						
SMKCAR	0.15	0.12	0.10	0.14						
SMKAMT	0.06	0.05	0.07	0.04						
SMKEXP2	-0.06	0.01	0.01	0.02						
IH	0.02	0.15	0.14							
OH	0.07	-0.11	-0.12							
IW	-0.06	-0.01	-0.00							
OW	0.05	0.03	0.02							
IA	0.09	0.04	0.04							
OA	-0.07	-0.11	-0.10							
T	0.07	0.14	0.13							
OCON3	-0.05	0.10								
ICON3	0.76									
R	0.82	0.55	0.54	0.49	0.32	0.29	0.25	0.22	0.14	0.09

Figure 75: Results of Model of Personal Exposure to Benzene

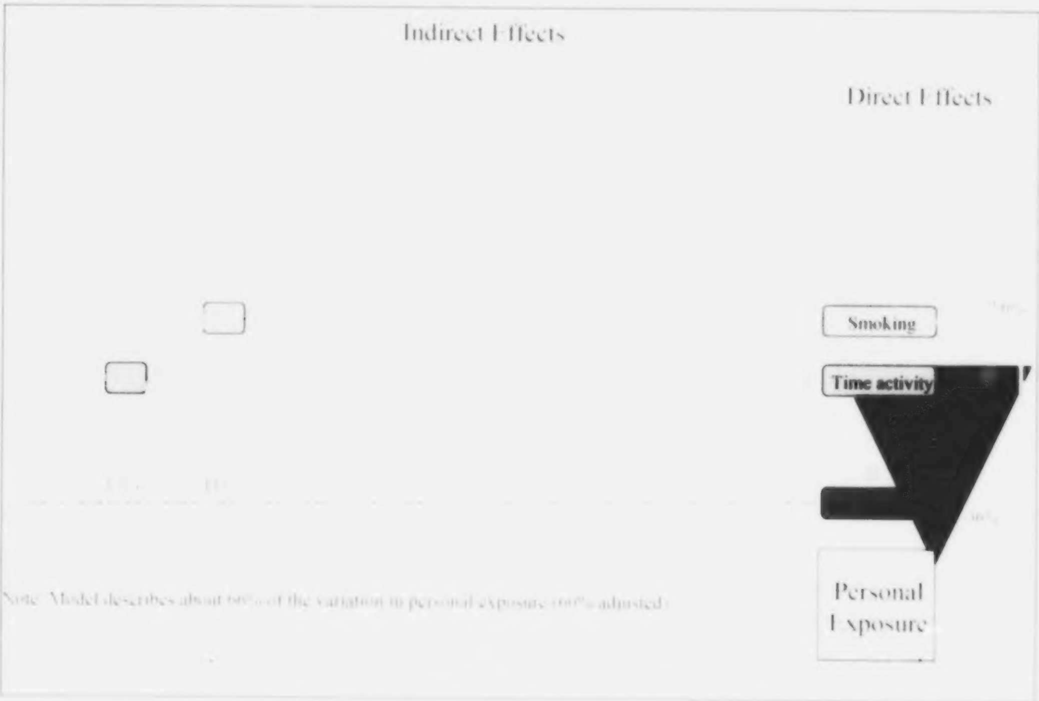


Note: Model describes about 66% of the variation in personal exposure (60% adjusted).

The model predicted about 66% of the variation (60% adjusted) in personal benzene exposure across individuals and days. Important factors influencing variations in personal exposure were:

- ***Indoor Levels***, directly, (36%)
- ***Smoking***, directly, (2.6%)
- ***Time Activity***, operating indirectly apparently through effects on indoor levels (3.3%)
- ***Smoking***, operating indirectly through indoor levels (11%)

Figure 75: Results of Model of Personal Exposure to Benzene


Indirect Effects
Direct Effects
Smoking
Time activity
Personal Exposure
Note: Model describes about 66% of the variation in personal exposure (60% adjusted)

The model predicted about 66% of the variation (60% adjusted) in personal benzene exposure across individuals and days. Important factors influencing variations in personal exposure were:

- ***Indoor Levels***, directly, (36%)
- ***Smoking***, directly, (2.6%)
- ***Time Activity***, operating indirectly apparently through effects on indoor levels (3.3%)
- ***Smoking***, operating indirectly through indoor levels (11%)

Toluene

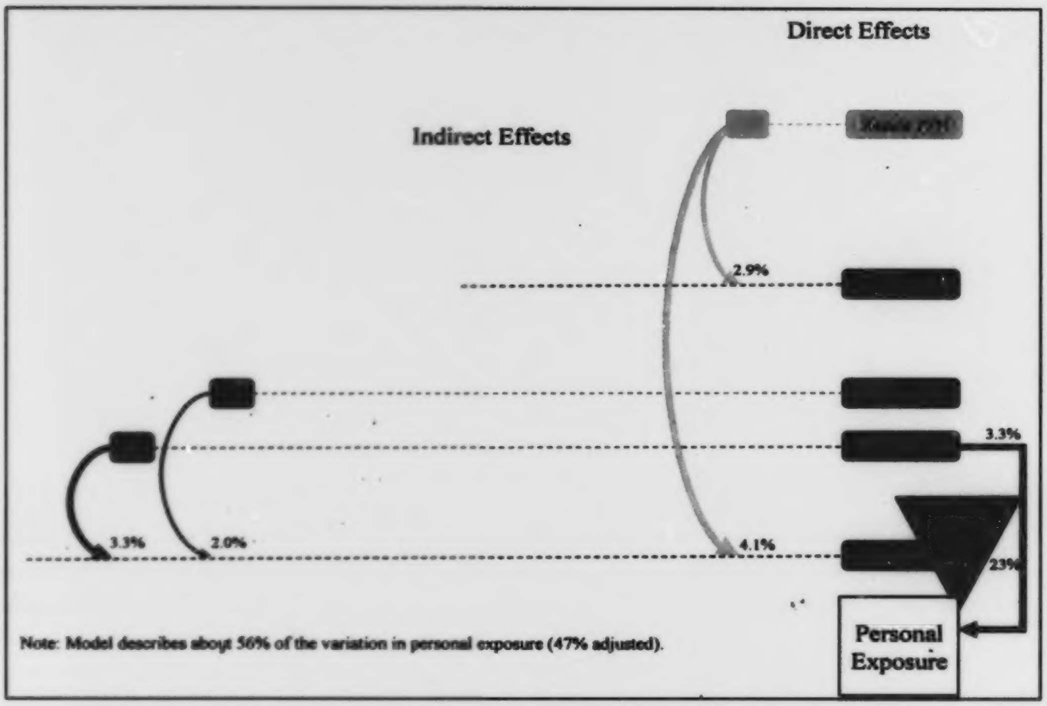
Table 24: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.05	0.05	0.08
Resident of PFN	0.34	0.33	0.09
Urban	0.07	0.15	0.07
Housing Characteristics	0.27	0.13	0.14
Garage	0.37	0.18	0.09
Job Status	0.13	0.14	0.10
Smoking Characteristics	0.21	0.23	0.13
Time Activity	0.30	0.26	0.18
Outdoor Concentration	0.05	0.04	0.03
Indoor Concentration	0.66	0.48	0.48

Table 25: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.10	0.10	0.10	-0.01	0.01	0.01	0.01	0.00	-0.01	-0.05
Resident of PFN	-0.18	-0.34	-0.35	-0.41	-0.29	-0.27	-0.39	-0.44	-0.34	
URBAN	-0.10	-0.17	-0.16	-0.10	-0.13	-0.13	-0.17	-0.18		
TRAILOR	-0.10	-0.10	-0.10	-0.08	-0.06	-0.04	-0.09			
MULT2	-0.05	-0.08	-0.08	-0.07	-0.05	-0.05	-0.08			
MED	0.05	0.06	0.06	0.06	0.04	0.05	0.03			
OLD	0.10	0.09	0.10	0.05	0.50	0.05	0.03			
NFCDAIR	0.08	0.17	0.16	0.14	0.11	0.10	0.08			
CARET	0.01	-0.01	-0.01	0.02	0.01	0.01	0.06			
ATTG	0.09	0.25	0.25	0.20	0.23	0.24				
DETG	0.13	0.17	0.14	0.14	0.15	0.16				
UNPAVED	0.06	0.13	0.12	0.14	0.12	0.13				
JOBFT	-0.07	-0.02	-0.02	-0.03	-0.01					
JOBPT	-0.13	-0.20	-0.18	-0.17	-0.15					
SMKHOME	0.14	0.22	0.23	0.21						
SMKCAR	-0.00	0.03	0.20	0.05						
SMKAMT	0.07	0.07	0.08	0.07						
SMKEXP2	-0.06	-0.08	-0.08	-0.08						
IH	0.10	0.13	0.13							
OH	-0.03	-0.17	-0.18							
IW	0.08	0.06	0.06							
OW	-0.04	-0.07	-0.08							
IA	0.14	0.11	0.11							
OA	-0.05	-0.11	-0.10							
T	0.04	0.04	0.04							
OCON3	-0.03	0.06								
ICON3	0.55									
R	0.75	0.58	0.57	0.51	0.45	0.43	0.39	0.37	0.34	0.05

Figure 76: Results of Model of Personal Exposure to Toluene

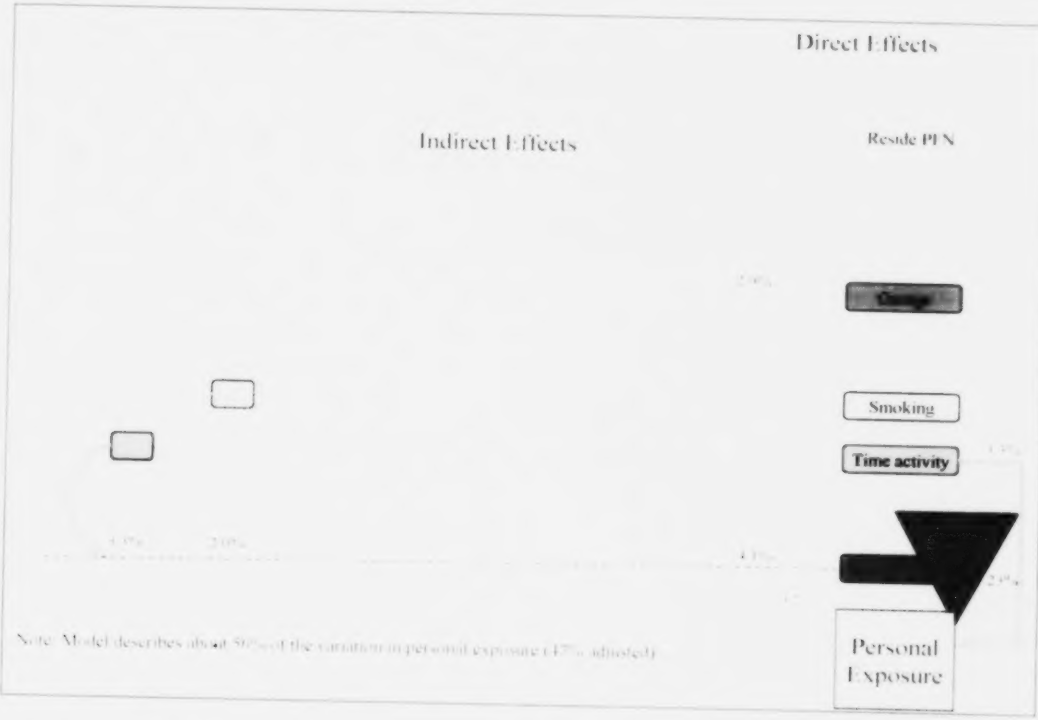


Note: Model describes about 56% of the variation in personal exposure (47% adjusted).

The model predicted about 56% of the variation (47% adjusted) in personal toluene exposure across individuals and days. Important factors influencing variations in toluene exposure were as follows:

- ***Indoor levels,*** directly (23%)
- ***Time Activity,*** directly (3.3%)
- ***Reside at Paul First Nation,*** operating indirectly on having a garage attached to the home (2.9%)
- ***Reside at Paul First Nation,*** operating indirectly on indoor levels (4.1%)
- ***Smoking,*** indirectly on indoor levels (2.0%)
- ***Time Activity,*** indirectly, operating on indoor levels (3.3%)

Figure 76: Results of Model of Personal Exposure to Toluene



The model predicted about 56% of the variation (47% adjusted) in personal toluene exposure across individuals and days. Important factors influencing variations in toluene exposure were as follows:

- ***Indoor levels***, directly (23%)
- ***Time Activity***, directly (3.3%)
- ***Reside at Paul First Nation***, operating indirectly on having a garage attached to the home (2.9%)
- ***Reside at Paul First Nation***, operating indirectly on indoor levels (4.1%)
- ***Smoking***, indirectly on indoor levels (2.0%)
- ***Time Activity***, indirectly, operating on indoor levels (3.3%)

Ethylbenzene

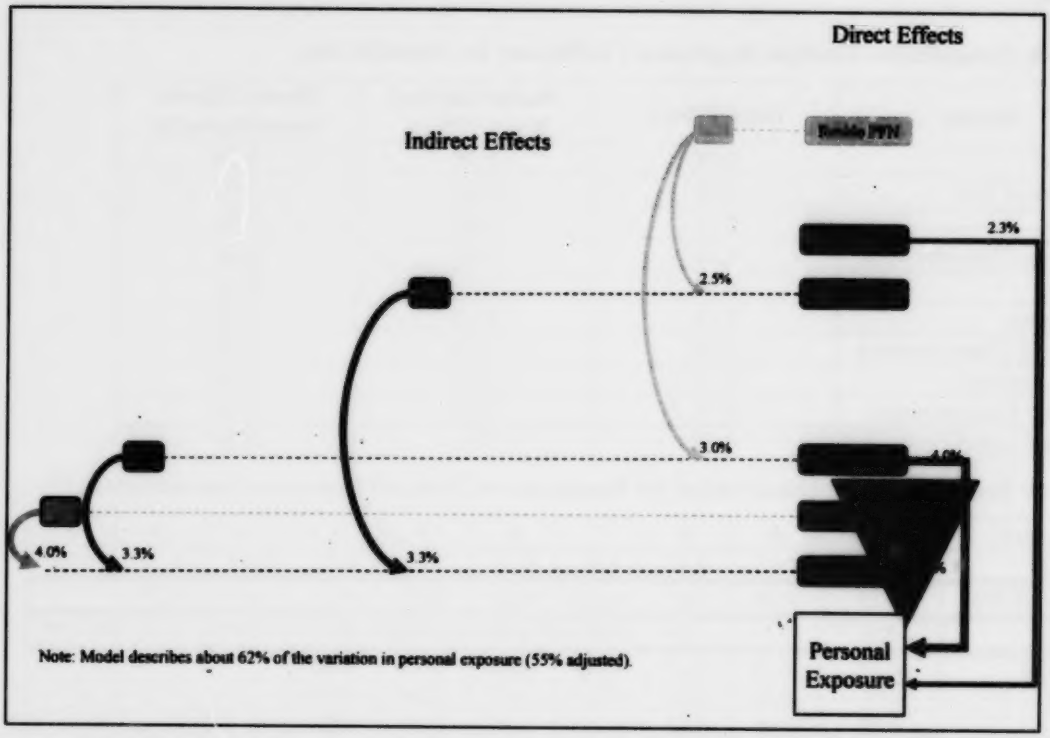
Table 26: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.05	0.05	0.10
Resident of PFN	0.30	0.29	0.05
Urban	0.11	0.07	0.07
Housing Characteristics	0.27	0.20	0.15
Garage	0.36	0.22	0.10
Job Status	0.10	0.12	0.11
Smoking Characteristics	0.24	0.16	0.13
Time Activity	0.30	0.27	0.20
Outdoor Concentration	0.14	0.20	0.00
Indoor Concentration	0.72	0.54	0.54

Table 27: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.12	0.18	0.18	0.09	0.11	0.10	0.10	0.10	0.09	0.06
Resident of PFN	-0.11	-0.08	-0.10	-0.20	-0.18	-0.19	-0.31	-0.35	-0.30	
URBAN	-0.10	-0.12	-0.08	-0.02	-0.04	-0.05	-0.08	-0.09		
TRAILOR	-0.08	-0.12	-0.13	-0.10	-0.08	-0.07	-0.13			
MULT2	-0.01	-0.14	-0.12	-0.11	-0.09	-0.09	-0.12			
MED	0.08	0.06	0.09	0.09	0.08	0.08	0.04			
OLD	0.07	0.06	0.07	0.02	0.02	0.02	-0.04			
NFCDAIR	0.10	0.20	0.19	0.16	0.15	0.14	0.13			
CARET	-0.04	-0.03	-0.04	-0.02	-0.01	-0.02	0.04			
ATTG	0.12	0.36	0.33	0.28	0.30	0.30				
DETG	0.12	0.15	0.16	0.12	0.13	0.14				
UNPAVED	0.00	0.12	0.12	0.14	0.14	0.14				
JOBFT	-0.08	-0.02	-0.04	-0.08	-0.07					
JOBPT	-0.14	-0.20	-0.16	-0.15	-0.14					
SMKHOME	0.15	0.22	0.22	0.21						
SMKCAR	-0.05	-0.04	-0.06	-0.02						
SMKAMT	0.06	-0.04	-0.05	-0.05						
SMKEXP2	-0.07	-0.03	-0.03	-0.04						
IH	0.06	0.18	0.17							
OH	-0.01	-0.10	-0.11							
IW	0.06	0.04	0.05							
OW	-0.01	-0.03	-0.05							
IA	0.12	0.12	0.14							
OA	-0.14	-0.21	-0.15							
T	0.04	0.05	0.04							
OCON3	0.01	0.23								
ICON3	0.65									
R	0.79	0.58	0.55	0.47	0.44	0.42	0.37	0.31	0.30	0.06

Figure 77: Results of Model of Personal Exposure to Ethylbenzene

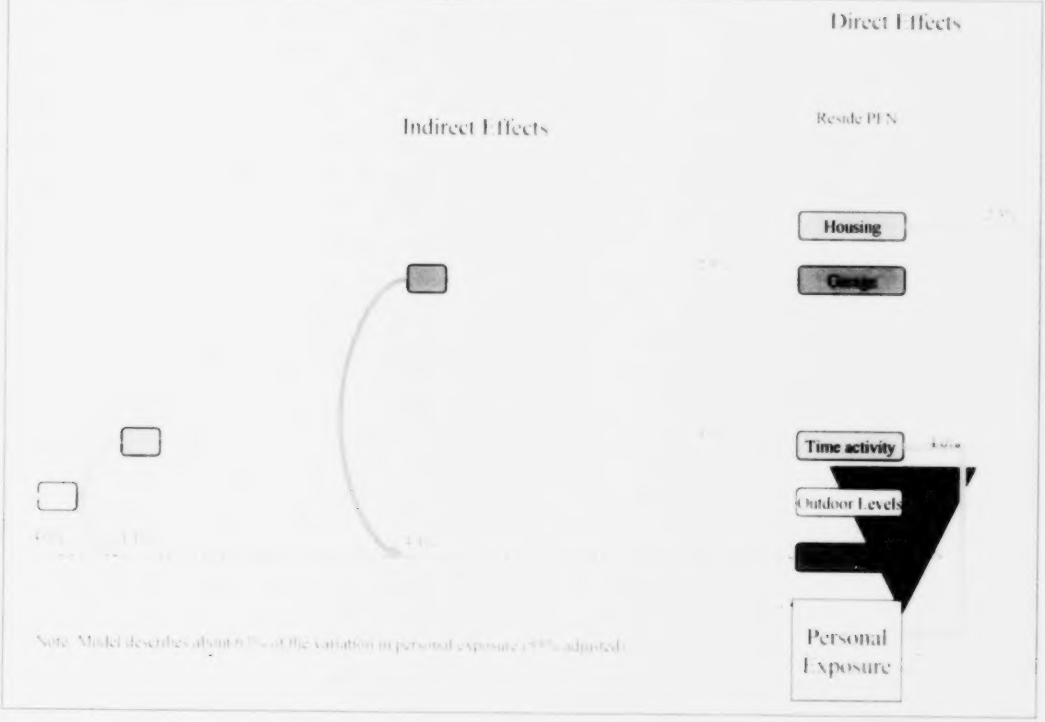


Note: Model describes about 62% of the variation in personal exposure (55% adjusted).

The model predicted about 62% of the variation (55% adjusted) in personal ethylbenzene exposure across individuals and days. Important factors influencing variations ethylbenzene exposure were as follows:

- ***Indoor levels,*** directly (29%)
- ***Time Activity,*** directly (4.0%) and indirectly via indoor levels (3.3%)
- ***Housing,*** directly (2.3%)
- ***Reside at Paul First Nation,*** operating indirectly on having a garage attached to the home (2.5%)
- ***Reside at Paul First Nation,*** operating indirectly on time activity (3.0%)
- ***Garage,*** operating indirectly on indoor levels (3.3%)
- ***Outdoors,*** operating indirectly on indoor levels (4.0%)

Figure 77: Results of Model of Personal Exposure to Ethylbenzene



The model predicted about 62% of the variation (55% adjusted) in personal ethylbenzene exposure across individuals and days. Important factors influencing variations ethylbenzene exposure were as follows:

- ***Indoor levels***, directly (29%)
- ***Time Activity***, directly (4.0%) and indirectly via indoor levels (3.3%)
- ***Housing***, directly (2.3%)
- ***Reside at Paul First Nation***, operating indirectly on having a garage attached to the home (2.5%)
- ***Reside at Paul First Nation***, operating indirectly on time activity (3.0%)
- ***Garage***, operating indirectly on indoor levels (3.3%)
- ***Outdoors***, operating indirectly on indoor levels (4.0%)

o-Xylene

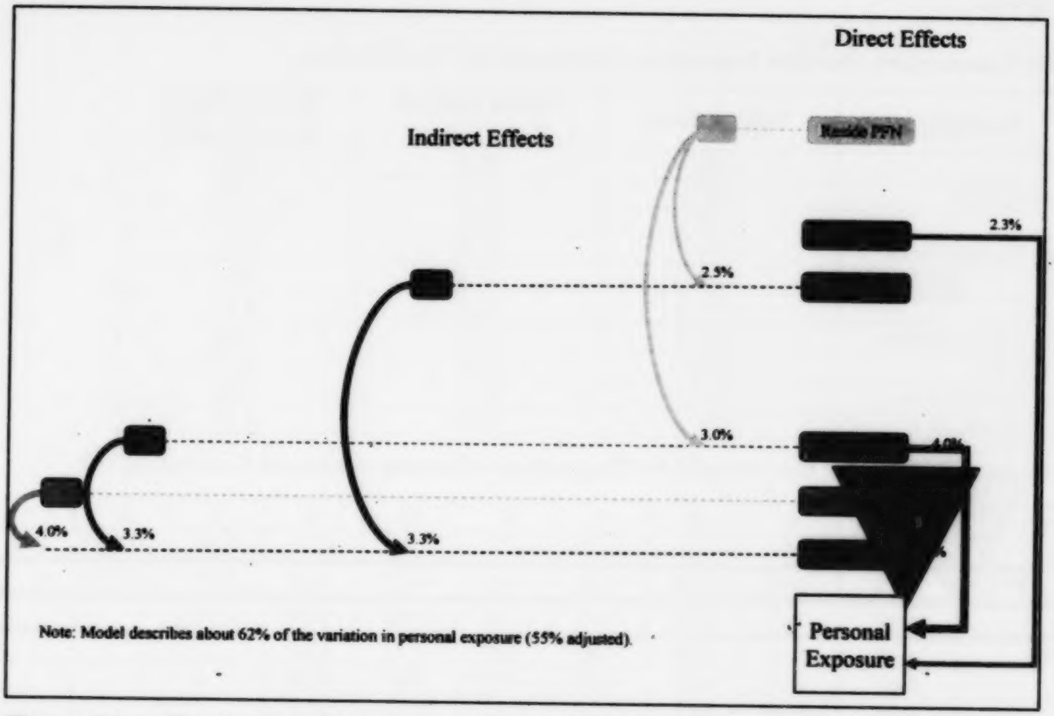
Table 28: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.08	0.08	0.08
Resident of PFN	0.32	0.31	0.03
Urban	0.13	0.06	0.04
Housing Characteristics	0.26	0.20	0.08
Garage	0.36	0.22	0.09
Job Status	0.14	0.15	0.09
Smoking Characteristics	0.30	0.18	0.13
Time Activity	0.32	0.25	0.16
Outdoor Concentration	0.15	0.20	0.00
Indoor Concentration	0.76	0.55	0.55

Table 29: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.09	0.15	0.17	0.10	0.13	0.12	0.12	0.12	0.12	0.08
Resident of PFN	-0.07	-0.06	-0.07	-0.16	-0.19	-0.21	-0.35	-0.35	-0.31	
URBAN	-0.07	-0.11	-0.06	-0.01	-0.02	-0.04	-0.07	-0.07		
TRAILOR	-0.05	-0.08	-0.07	-0.06	-0.03	-0.02	-0.08			
MULT2	0.01	-0.12	-0.10	-0.09	-0.07	-0.06	-0.09			
MED	0.04	0.08	0.12	0.11	0.10	0.10	0.06			
OLD	0.00	0.01	0.04	-0.02	-0.02	-0.03	-0.08			
NFCDAIR	0.04	0.21	0.19	0.16	0.16	0.14	0.13			
CARET	-0.02	-0.06	-0.06	-0.04	-0.00	-0.02	-0.03			
ATTG	0.06	0.35	0.32	0.28	0.31	0.30				
DETG	0.14	0.18	0.17	0.13	0.16	0.16				
UNPAVED	0.02	0.11	0.11	0.14	0.13	0.13				
JOBFT	-0.05	-0.05	-0.06	-0.12	-0.12					
JOBPT	-0.12	-0.23	-0.17	-0.18	-0.16					
SMKHOME	0.18	0.24	0.22	0.21						
SMKCAR	-0.08	-0.05	-0.07	-0.03						
SMKAMT	0.01	-0.11	-0.12	-0.14						
SMKEXP2	-0.07	-0.06	-0.07	-0.07						
IH	0.03	0.18	0.17							
OH	-0.02	-0.04	-0.05							
IW	0.02	0.01	0.01							
OW	0.06	0.03	0.00							
IA	0.09	0.07	0.09							
OA	-0.13	-0.23	-0.17							
T	0.06	0.09	0.09							
OCON3	-0.01	0.24								
ICON3	0.71									
R	0.81	0.59	0.56	0.50	0.47	0.44	0.38	0.33	0.32	0.08

Figure 78: Results of Model of Personal Exposure to *o*-Xylene

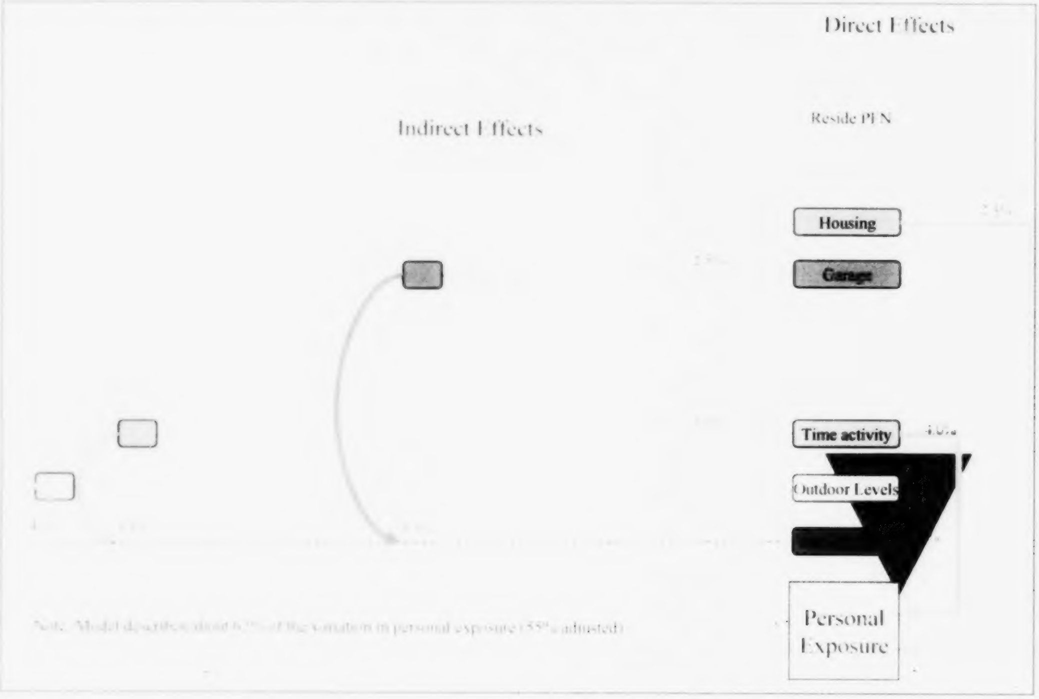


Note: Model describes about 62% of the variation in personal exposure (55% adjusted).

The model predicted about 62% of the variation (55% adjusted) in personal *o*-Xylene exposure across individuals and days. Important factors influencing variations in *o*-Xylene exposure were as follows:

- ***Indoor levels,*** directly (29%)
- ***Time Activity,*** directly (4.0%) and indirectly on indoor levels (3.3%)
- ***Housing,*** directly (2.3%)
- ***Reside at Paul First Nation,*** operating indirectly on having an attached garage (2.5%)
- ***Reside at Paul First Nation,*** operating indirectly on time activity (3.0%)
- ***Garage,*** operating indirectly on indoor level (3.3%)
- ***Outdoor levels,*** operating indirectly on indoor levels (4.0%)

Figure 78: Results of Model of Personal Exposure to *o*-Xylene



The model predicted about 62% of the variation (55% adjusted) in personal *o*-Xylene exposure across individuals and days. Important factors influencing variations in *o*-Xylene exposure were as follows:

- ***Indoor levels***, directly (29%)
- ***Time Activity***, directly (4.0%) and indirectly on indoor levels (3.3%)
- ***Housing***, directly (2.3%)
- ***Reside at Paul First Nation***, operating indirectly on having an attached garage (2.5%)
- ***Reside at Paul First Nation***, operating indirectly on time activity (3.0%)
- ***Garage***, operating indirectly on indoor level (3.3%)
- ***Outdoor levels***, operating indirectly on indoor levels (4.0%)

m-, p - Xylene

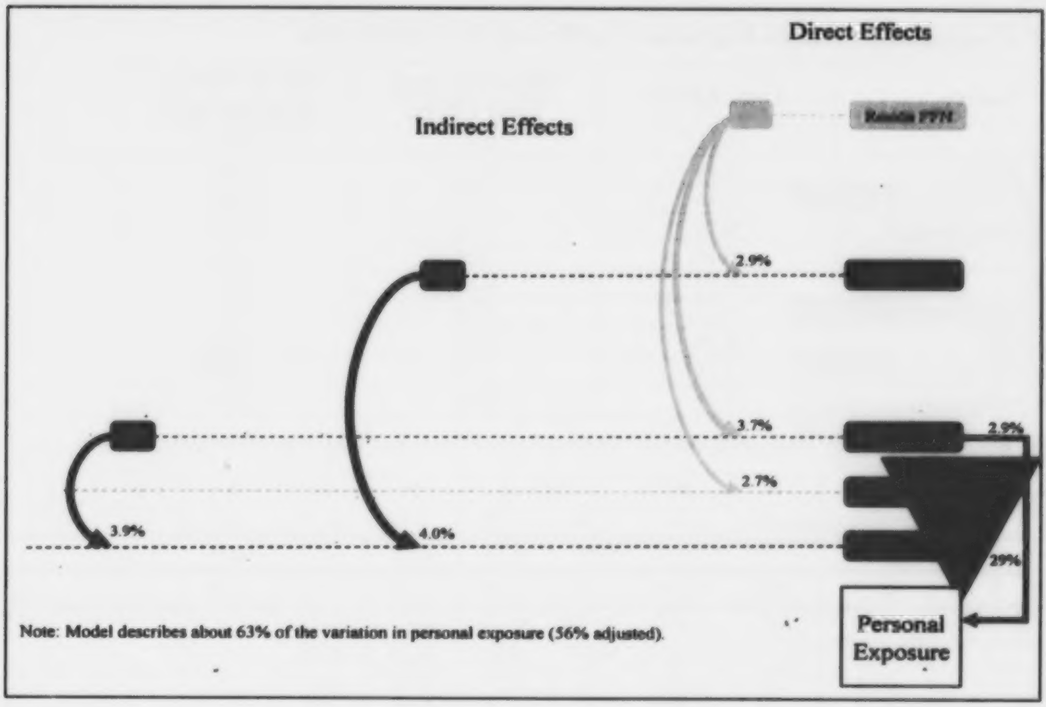
Table 30: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.05	0.05	0.09
Resident of PFN	0.33	0.33	0.06
Urban	0.12	0.08	0.05
Housing Characteristics	0.26	0.18	0.14
Garage	0.39	0.24	0.11
Job Status	0.11	0.12	0.10
Smoking Characteristics	0.29	0.17	0.10
Time Activity	0.32	0.26	0.17
Outdoor Concentration	0.14	0.15	0.06
Indoor Concentration	0.73	0.54	0.54

Table 31: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.11	0.15	0.17	0.09	0.12	0.11	0.11	0.10	0.10	0.06
Resident of PFN	-0.13	-0.05	-0.08	-0.20	-0.21	-0.22	-0.37	-0.39	-0.33	
URBAN	-0.09	-0.13	-0.08	-0.03	-0.04	-0.05	-0.09	-0.10		
TRAILOR	-0.07	-0.10	-0.09	-0.06	-0.04	-0.03	-0.09			
MULT2	0.02	-0.09	-0.08	-0.08	-0.05	-0.05	-0.09			
MED	0.09	0.10	0.13	0.12	0.12	0.12	0.08			
OLD	0.06	0.07	0.10	0.05	0.05	0.04	-0.02			
NFCDAIR	0.06	0.19	0.17	0.15	0.15	0.13	0.12			
CARET	-0.04	-0.07	-0.06	-0.04	-0.02	-0.03	0.03			
ATTG	0.08	0.39	0.40	0.31	0.33	0.33				
DETG	0.16	0.20	0.19	0.15	0.17	0.17				
UNPAVED	0.05	0.16	0.14	0.16	0.16	0.15				
JOBFT	-0.08	-0.05	-0.05	-0.10	-0.09					
JOBPT	-0.12	-0.16	-0.15	-0.15	-0.13					
SMKHOME	0.14	0.20	0.20	0.19						
SMKCAR	-0.05	-0.01	-0.03	0.01						
SMKAMT	0.01	-0.14	-0.12	-0.13						
SMKEXP2	-0.07	-0.03	-0.03	-0.04						
IH	0.03	0.20	0.19							
OH	-0.04	-0.04	-0.08							
IW	0.04	0.04	0.05							
OW	-0.00	-0.01	-0.04							
IA	0.12	0.14	0.14							
OA	-0.10	-0.17	-0.14							
T	0.04	0.05	0.05							
OCON3	-0.08	0.18								
ICON3	0.69									
R	0.80	0.59	0.57	0.50	0.47	0.45	0.39	0.34	0.33	0.06

Figure 79: Results of Model of Personal Exposure to *m*-, *p* - Xylene

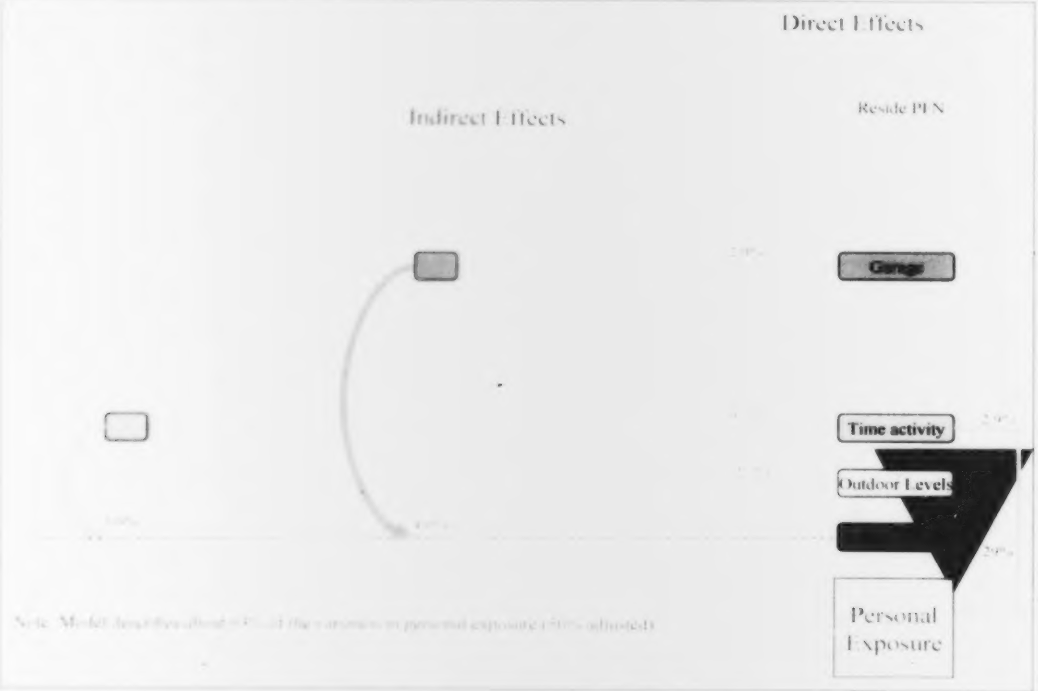


Note: Model describes about 63% of the variation in personal exposure (56% adjusted).

The model predicted 63% of the variation (56% adjusted) in personal *m, p*–Xylene exposure across individuals and days. Important factors influencing variations in *m, p*–Xylene exposure were as follows:

- ***Indoor levels,*** directly 29%
- ***Time Activity,*** directly (2.9%) and indirectly on indoor levels (3.9%)
- ***Reside at Paul First,*** operating indirectly:
  - On having a garage attached to the home (2.9%)
  - Time spent indoors (3.7%)
  - Outdoor levels (2.7%)
- ***Garage,*** operating indirectly on indoor levels (4.0%)

Figure 79: Results of Model of Personal Exposure to *m-, p* - Xylene



Note: Model describes about 63% of the variation in personal exposure (56% adjusted)

The model predicted 63% of the variation (56% adjusted) in personal *m, p* Xylene exposure across individuals and days. Important factors influencing variations in *m, p* Xylene exposure were as follows:

- ***Indoor levels,*** directly 29%
- ***Time Activity,*** directly (2.9%) and indirectly on indoor levels (3.9%)
- ***Reside at Paul First,*** operating indirectly:
    - On having a garage attached to the home (2.9%)
    - Time spent indoors (3.7%)
    - Outdoor levels (2.7%)
- ***Garage,*** operating indirectly on indoor levels (4.0%)

Limonene

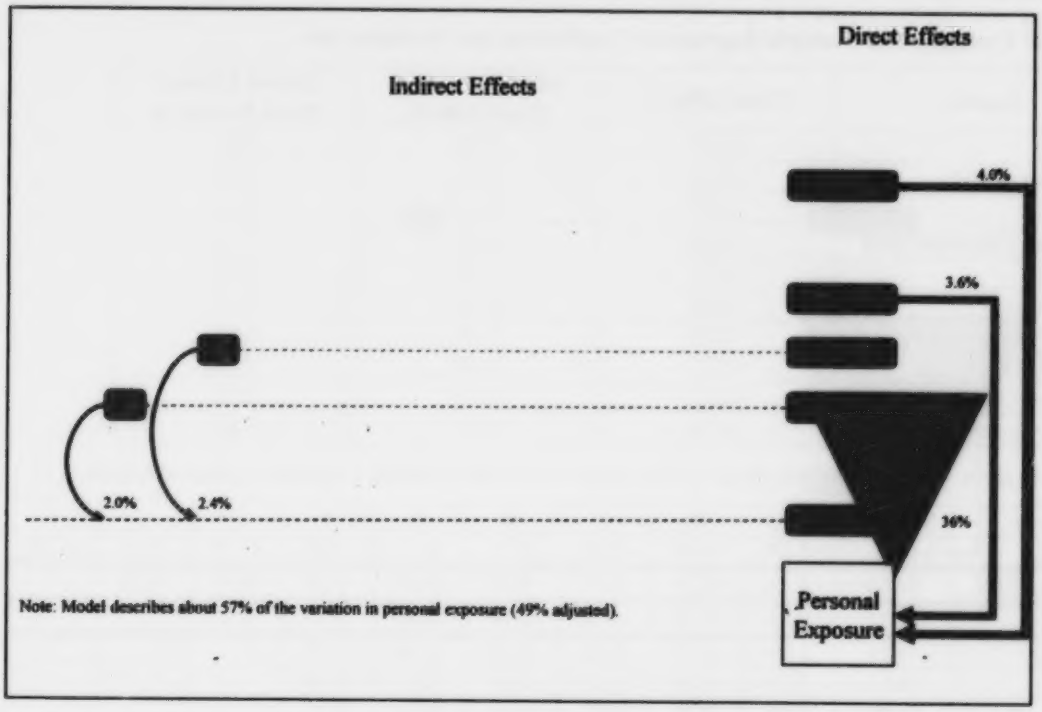
Table 32: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.11	0.11	0.04
Resident of PFN	0.18	0.14	0.00
Urban	0.14	0.07	0.08
Housing Characteristics	0.19	0.15	0.20
Garage	0.15	0.05	0.05
Job Status	0.17	0.18	0.19
Smoking Characteristics	0.22	0.22	0.14
Time Activity	0.16	0.20	0.14
Outdoor Concentration	0.11	0.18	0.14
Indoor Concentration	0.67	0.60	0.60

Table 33: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	-0.06	0.00	-0.01	-0.08	-0.08	-0.10	-0.10	-0.12	-0.12	-0.11
Resident of PFN	-0.03	0.10	0.13	0.06	0.14	0.11	0.12	0.09	0.14	
URBAN	-0.11	-0.05	-0.04	-0.01	-0.05	-0.06	-0.05	-0.09		
TRAILOR	-0.08	-0.03	-0.05	-0.03	-0.02	-0.01	0.00			
MULT2	-0.06	-0.05	-0.07	-0.07	-0.06	-0.05	-0.05			
MED	0.14	0.10	0.12	0.10	0.10	0.09	0.10			
OLD	0.14	0.22	0.19	0.15	0.13	0.12	0.14			
NFCDAIR	0.12	0.20	0.17	0.15	0.14	0.11	0.11			
CARET	0.08	0.01	0.01	0.03	0.04	0.02	0.01			
ATTG	-0.05	-0.01	-0.03	-0.07	-0.04	-0.05				
DETG	-0.02	0.05	0.03	-0.00	0.01	0.01				
UNPAVED	-0.06	-0.03	-0.03	-0.02	-0.04	-0.04				
JOBFT	-0.19	-0.24	-0.21	-0.17	-0.15					
JOBPT	-0.23	-0.30	-0.25	-0.21	-0.19					
SMKHOME	0.07	0.05	0.03	0.00						
SMKCAR	0.07	0.11	0.14	0.17						
SMKAMT	0.05	0.13	0.08	0.08						
SMKEXP2	-0.13	-0.21	-0.19	-0.19						
IH	0.06	0.08	0.08							
OH	-0.07	-0.11	-0.09							
IW	0.10	0.16	0.12							
OW	-0.01	-0.02	-0.04							
IA	0.02	0.09	0.13							
OA	-0.06	-0.11	-0.09							
T	-0.08	-0.01	0.00							
OCON3	0.15	0.20								
ICON3	0.65									
R	0.76	0.47	0.43	0.38	0.31	0.25	0.25	0.19	0.18	0.11

Figure 80: Results of Model of Personal Exposure to Limonene

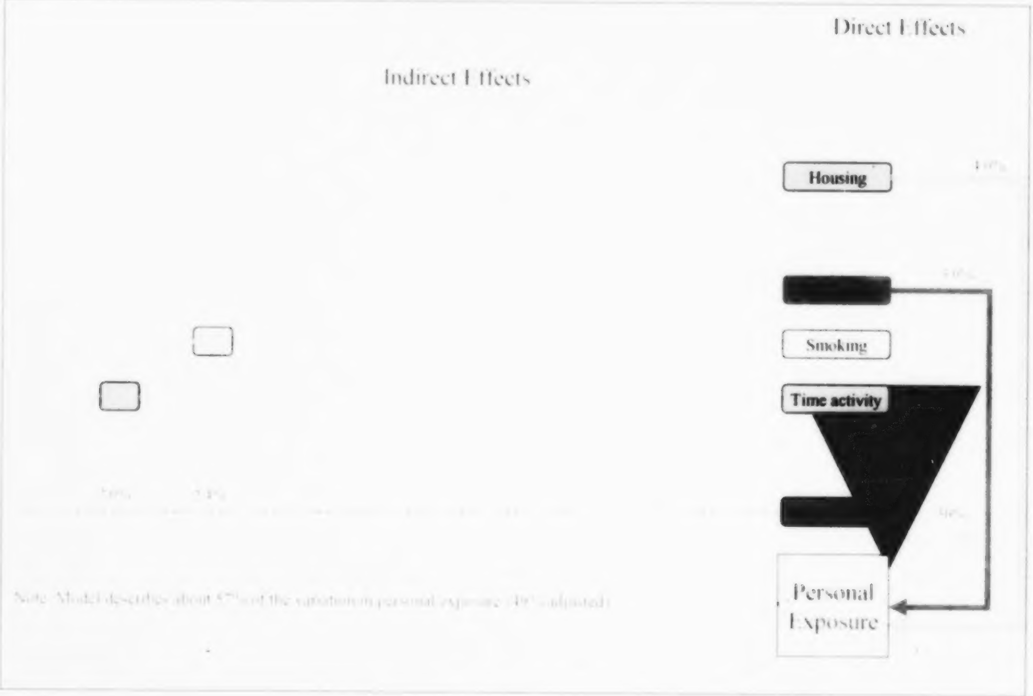


Note: Model describes about 57% of the variation in personal exposure (49% adjusted).

The model predicted about 57% of the variation (49 % adjusted) in personal limonene exposure across individuals and days. Important factors influencing variations in exposure were as follows:

- ***Indoor levels,*** directly (36%)
- ***Job Status,*** directly (3.6%)
- ***Housing,*** directly (4.0%)
- ***Smoking,*** indirectly on indoor levels (2.4%)
- ***Time Activity***, indirectly on indoor levels (2.0%)

Figure 80: Results of Model of Personal Exposure to Limonene



Note: Model describes about 57% of the variation in personal exposure (49% adjusted)

The model predicted about 57% of the variation (49 % adjusted) in personal limonene exposure across individuals and days. Important factors influencing variations in exposure were as follows:

- ***Indoor levels***, directly (36%)
- ***Job Status***, directly (3.6%)
- ***Housing***, directly (4.0%)
- ***Smoking***, indirectly on indoor levels (2.4%)
- ***Time Activity***, indirectly on indoor levels (2.0%)

Hexane

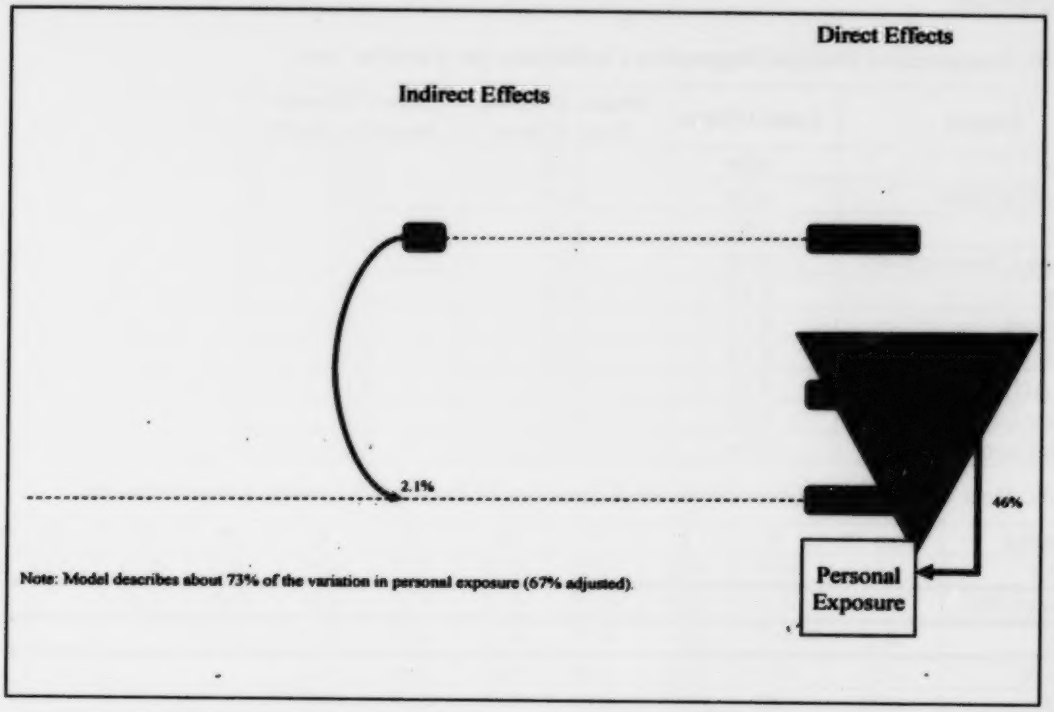
Table 34: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.09	0.09	0.04
Resident of PFN	0.28	0.26	0.06
Urban	0.05	0.13	0.06
Housing Characteristics	0.26	0.21	0.12
Garage	0.31	0.18	0.08
Job Status	0.08	0.10	0.06
Smoking Characteristics	0.28	0.18	0.07
Time Activity	0.21	0.20	0.18
Outdoor Concentration	0.15	0.14	0.03
Indoor Concentration	0.79	0.68	0.68

Table 35: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.06	0.18	0.20	0.12	0.14	0.13	0.13	0.14	0.13	0.10
Resident of PFN	-0.13	-0.14	-0.19	-0.24	-0.32	-0.31	-0.34	-0.35	-0.26	
URBAN	-0.09	-0.21	-0.23	-0.18	-0.18	-0.19	-0.19	-0.15		
TRAILOR	-0.10	-0.19	-0.19	-0.18	-0.15	-0.14	-0.17			
MULT2	-0.03	-0.03	-0.04	-0.03	0.00	0.00	-0.00			
MED	0.08	0.04	0.05	0.07	0.07	0.08	0.04			
OLD	0.01	-0.03	-0.01	-0.01	-0.01	-0.01	-0.10			
NFCDAIR	0.01	0.06	0.03	0.02	0.02	0.01	0.02			
CARET	0.02	-0.02	-0.02	-0.01	0.02	0.02	0.05			
ATTG	-0.11	0.22	0.17	0.16	0.18	0.19				
DETG	-0.02	-0.02	-0.06	-0.08	-0.06	-0.05				
UNPAVED	-0.05	0.04	0.04	0.05	0.05	0.05				
JOBFT	-0.01	0.06	0.10	-0.01	-0.03					
JOBPT	-0.07	-0.10	-0.08	-0.11	-0.11					
SMKHOME	0.06	0.12	0.16	0.18						
SMKCAR	0.01	-0.05	-0.11	-0.11						
SMKAMT	-0.03	-0.15	-0.14	0.13						
SMKEXP2	-0.08	-0.10	0.10	0.11						
IH	0.05	0.04	0.05							
OH	0.15	-0.08	-0.09							
IW	-0.07	-0.13	-0.12							
OW	-0.01	-0.10	-0.12							
IA	0.05	0.02	0.03							
OA	-0.11	-0.10	-0.08							
T	0.06	-0.04	-0.05							
OCON3	-0.03	0.17								
ICON3	0.82									
R	0.85	0.52	0.50	0.46	0.43	0.41	0.37	0.31	0.28	0.10

Figure 81: Results of Model of Personal Exposure to Hexane

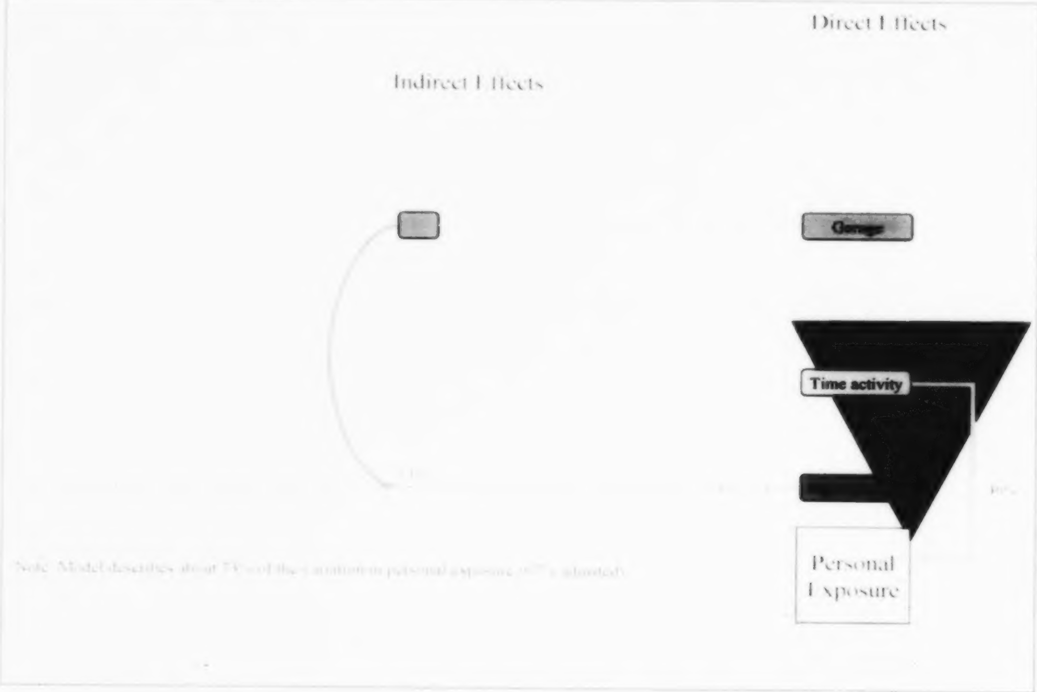


Note: Model describes about 73% of the variation in personal exposure (67% adjusted).

The model predicted about 73% of the variation (67% adjusted) in personal hexane exposure across individuals and days. Important factors influencing variations in hexane exposure were as follows:

- ***Indoor levels,*** directly (46%)
- ***Time Activity,*** directly (3.2%)
- ***Garage,*** indirectly, operating on having a garage attached to the home (2.1%)

Figure 81: Results of Model of Personal Exposure to Hexane


Direct Effects
Indirect Effects
Garage
Time activity
Personal Exposure
Note: Model describes about 73% of the variation in personal exposure (67% adjusted)

The model predicted about 73% of the variation (67% adjusted) in personal hexane exposure across individuals and days. Important factors influencing variations in hexane exposure were as follows:

- ***Indoor levels***, directly (46%)
- ***Time Activity***, directly (3.2%)
- ***Garage***, indirectly, operating on having a garage attached to the home (2.1%)

3-Methylhexane

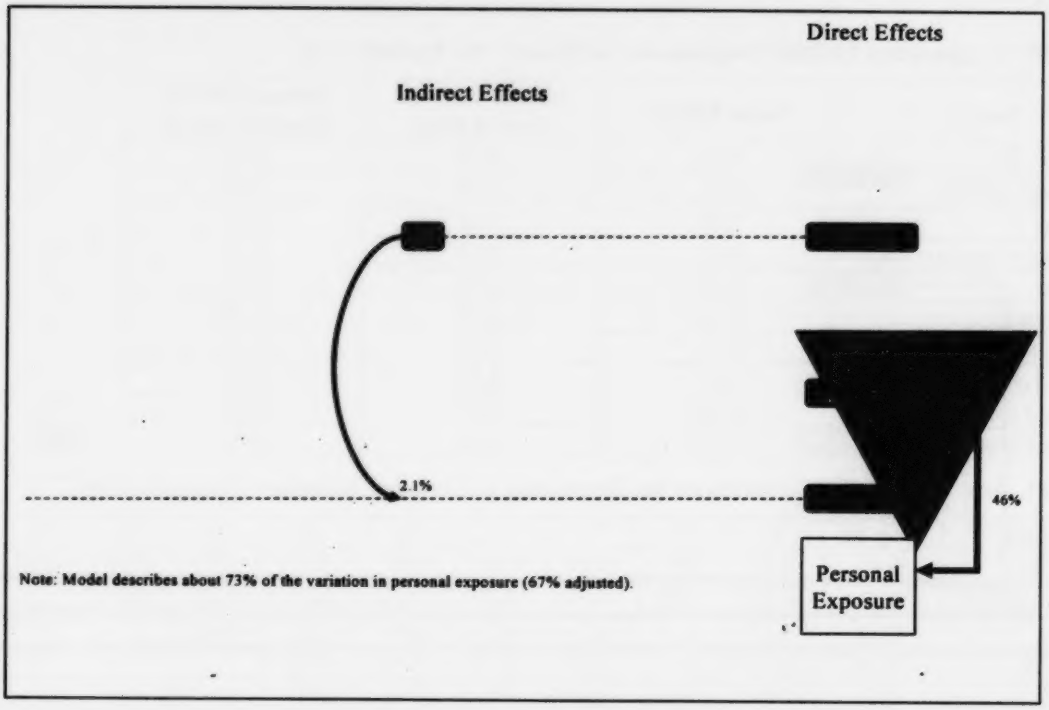
Table 36: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.08	0.08	0.00
Resident of PFN	0.20	0.19	0.06
Urban	0.01	0.14	0.10
Housing Characteristics	0.18	0.15	0.13
Garage	0.19	0.18	0.06
Job Status	0.11	0.10	0.09
Smoking Characteristics	0.18	0.13	0.11
Time Activity	0.25	0.23	0.17
Outdoor Concentration	0.07	0.14	0.05
Indoor Concentration	0.76	0.67	0.67

Table 37: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.01	0.00	0.02	-0.05	-0.03	-0.04	-0.04	-0.05	-0.06	-0.08
Resident of PFN	-0.14	-0.29	-0.29	-0.31	-0.32	-0.32	-0.29	-0.29	-0.19	
URBAN	-0.15	-0.27	-0.23	-0.19	-0.21	-0.22	-0.20	-0.18		
TRAILOR	-0.11	-0.13	-0.10	-0.09	-0.07	-0.06	-0.07			
MULT2	-0.00	-0.05	-0.06	-0.04	-0.03	-0.03	-0.02			
MED	0.09	0.15	0.16	0.15	0.16	0.16	0.12			
OLD	0.09	0.08	0.11	0.09	0.08	0.08	-0.02			
NFCDAIR	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.02			
CARET	-0.03	-0.06	-0.06	-0.03	-0.00	-0.01	0.00			
ATTG	0.00	0.14	0.11	0.07	0.09	0.10				
DETG	0.01	-0.10	-0.13	-0.18	-0.16	-0.15				
UNPAVED	-0.07	-0.02	-0.01	0.01	0.01	0.01				
JOBFT	-0.01	-0.01	-0.03	-0.03	-0.03					
JOBPT	-0.11	-0.15	-0.15	-0.13	-0.12					
SMKHOME	0.04	0.10	0.11	0.08						
SMKCAR	0.13	0.11	0.07	0.09						
SMKAMT	-0.07	-0.11	-0.10	-0.10						
SMKEXP2	-0.07	-0.10	-0.12	-0.10						
IH	-0.00	0.05	0.05							
OH	-0.02	-0.18	-0.17							
IW	-0.00	-0.02	-0.00							
OW	0.02	0.04	0.03							
IA	0.11	0.09	0.10							
OA	-0.11	-0.13	-0.11							
T	0.07	0.04	0.03							
OCON3	0.07	0.16								
ICON3	0.73									
R	0.82	0.47	0.45	0.38	0.36	0.34	0.29	0.25	0.20	0.08

Figure 82: Results of Model of Personal Exposure to *3*-Methylhexane

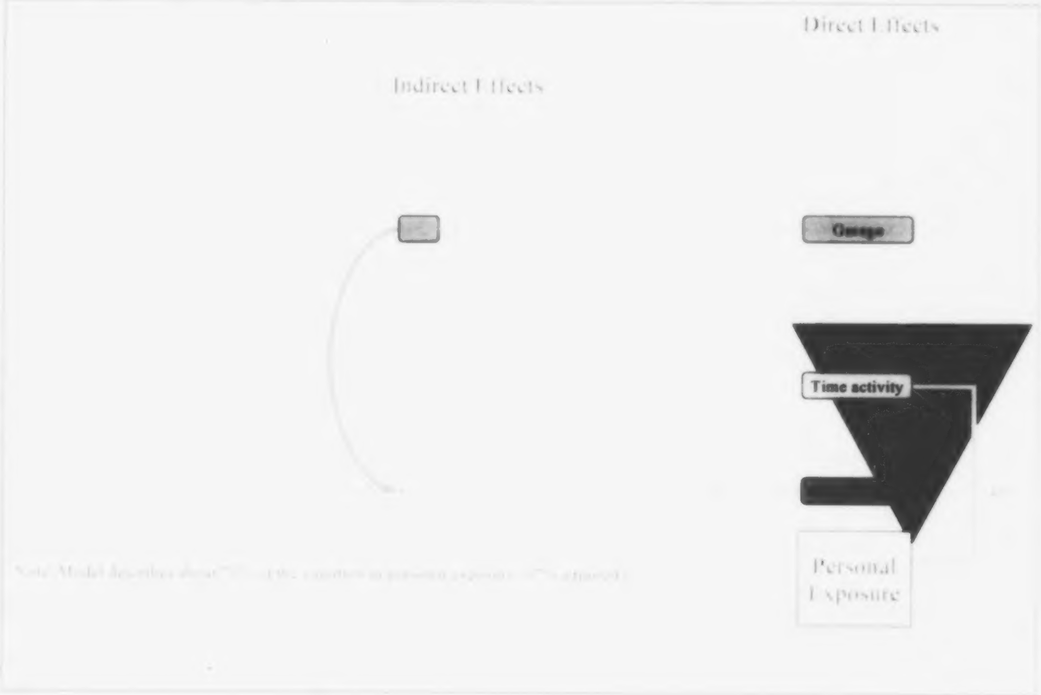


Note: Model describes about 73% of the variation in personal exposure (67% adjusted).

The model predicted about 73% of the variation in personal exposure (67% adjusted) to methylhexane across individuals and days. Important factors influencing variations were as follows:

- ***Indoor levels***, directly (46%)
- ***Time Activity***, directly (3.2%)
- ***Garage***, indirectly, operating on indoor levels (2.1%)

Figure 82: Results of Model of Personal Exposure to *3*-Methylhexane



The model predicted about 73% of the variation in personal exposure (67% adjusted) to methylhexane across individuals and days. Important factors influencing variations were as follows:

- ***Indoor levels***, directly (46%)
- ***Time Activity***, directly (3.2%)
- ***Garage***, indirectly, operating on indoor levels (2.1%)

Heptane

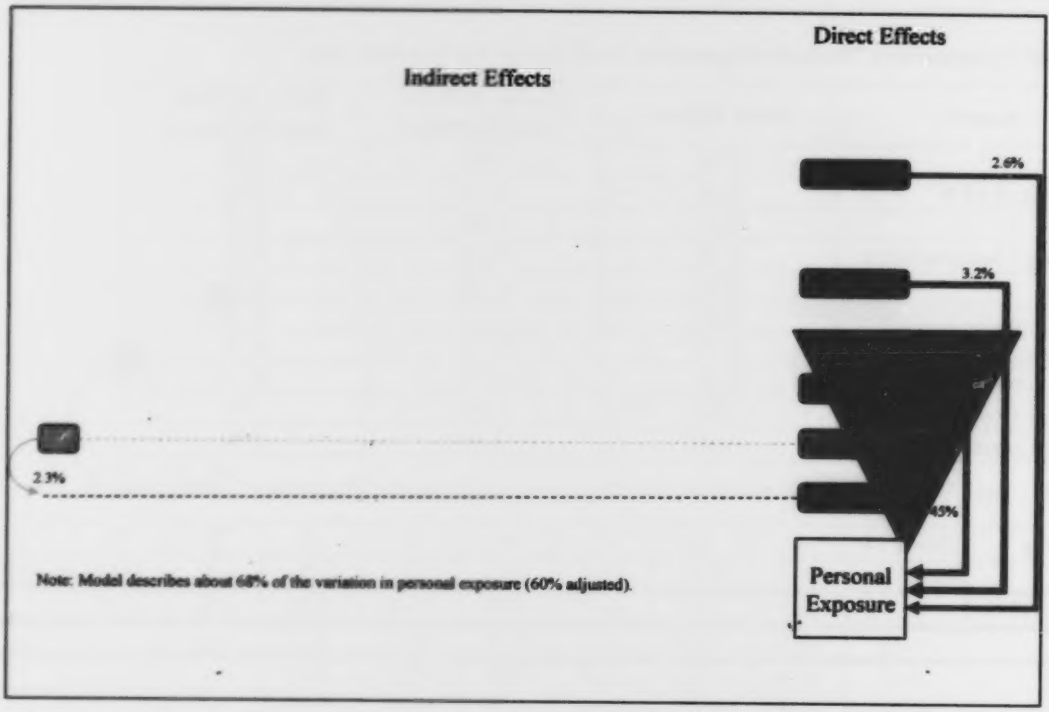
Table 38: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.10	0.10	0.03
Resident of PFN	0.21	0.19	0.05
Urban	0.01	0.14	0.13
Housing Characteristics	0.21	0.17	0.16
Garage	0.22	0.15	0.08
Job Status	0.14	0.17	0.18
Smoking Characteristics	0.17	0.11	0.11
Time Activity	0.21	0.20	0.18
Outdoor Concentration	0.10	0.17	0.08
Indoor Concentration	0.74	0.67	0.67

Table 39: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	-0.03	-0.03	0.00	-0.07	-0.07	-0.07	-0.07	-0.07	-0.08	-0.10
Resident of PFN	-0.12	-0.25	-0.26	-0.29	-0.31	-0.26	-0.27	-0.29	-0.19	
URBAN	-0.18	-0.27	-0.24	-0.20	-0.21	-0.20	-0.19	-0.18		
TRAILOR	-0.15	-0.17	-0.14	-0.12	-0.11	-0.08	-0.10			
MULT2	0.02	-0.04	-0.05	-0.05	-0.03	-0.04	-0.03			
MED	-0.01	0.08	0.10	0.09	0.09	0.12	0.08			
OLD	0.04	0.01	0.05	0.04	0.03	0.04	-0.04			
NFCDAIR	0.04	0.06	0.05	0.04	0.04	0.04	0.05			
CARET	0.05	-0.00	-0.00	0.01	0.04	0.05	0.07			
ATTG	-0.01	0.15	0.12	0.09	0.11	0.13				
DETG	-0.04	-0.06	-0.09	-0.12	-0.10	-0.08				
UNPAVED	0.08	-0.02	0.00	0.01	0.01	0.02				
JOBFT	0.09	0.08	0.08	0.08	0.08					
JOBPT	-0.14	-0.17	-0.16	-0.14	-0.13					
SMKHOME	0.06	0.07	0.08	0.06						
SMKCAR	0.03	0.06	0.01	0.03						
SMKAMT	-0.11	-0.09	-0.06	-0.05						
SMKEXP2	-0.09	-0.10	-0.12	-0.12						
IH	0.06	0.05	0.05							
OH	-0.06	-0.17	-0.17							
IW	0.04	0.01	0.01							
OW	0.04	0.02	-0.00							
IA	0.04	0.08	0.09							
OA	-0.15	-0.08	-0.08							
T	0.06	-0.03	-0.03							
OCON3	0.09	0.18								
ICON3	0.72									
R	0.82	0.48	0.45	0.40	0.38	0.34	0.31	0.26	0.21	0.10

Figure 83: Results of Model of Personal Exposure to Heptane

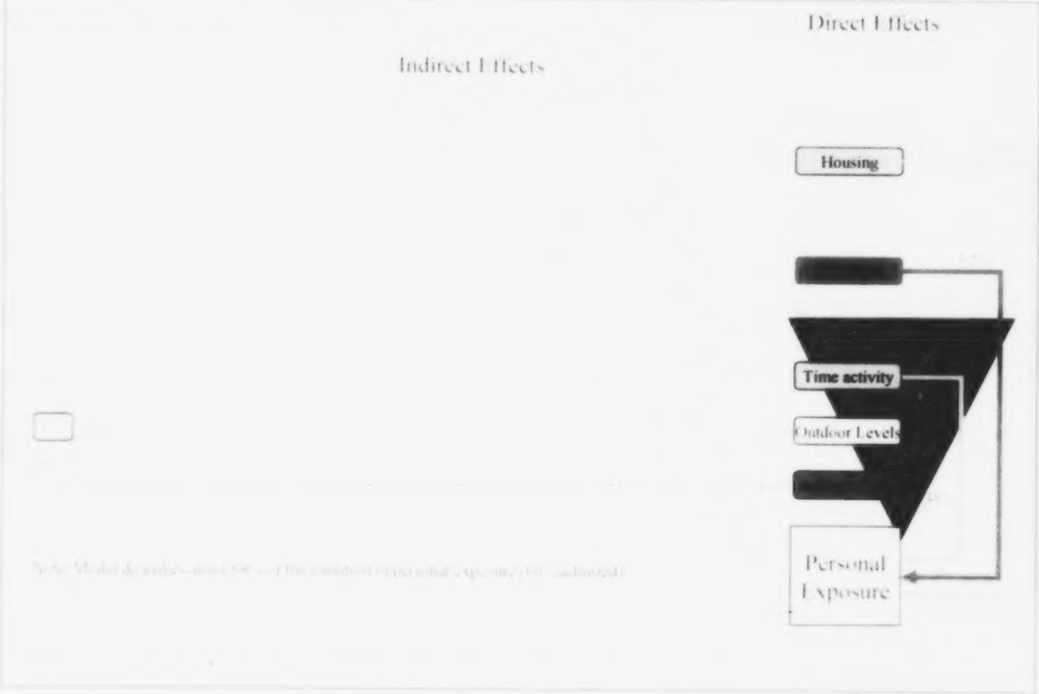


Note: Model describes about 68% of the variation in personal exposure (60% adjusted).

The model predicted about 68% of the variation (60% adjusted) in personal heptane exposure across individuals and days. Important factors influencing variations in heptane exposure were as follows:

- ***Indoor levels,*** directly (45%)
- ***Time Activity,*** directly (3.2%)
- ***Job Status,*** directly (3.2%)
- ***Housing,*** directly (2.6%)
- ***Outdoor levels,*** indirectly acting on indoor levels (2.3%)

Figure 83: Results of Model of Personal Exposure to Heptane



The model predicted about 68% of the variation (60% adjusted) in personal heptane exposure across individuals and days. Important factors influencing variations in heptane exposure were as follows:

- ***Indoor levels,*** directly (45%)
- ***Time Activity,*** directly (3.2%)
- ***Job Status,*** directly (3.2%)
- ***Housing,*** directly (2.6%)
- ***Outdoor levels,*** indirectly acting on indoor levels (2.3%)

Octane

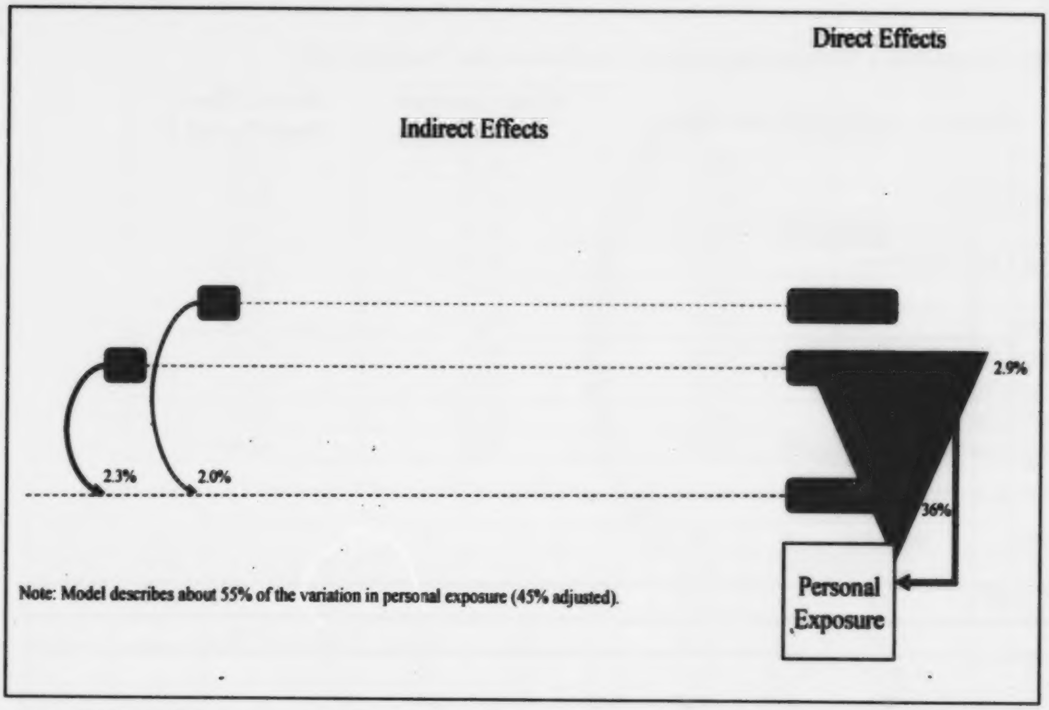
Table 40: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.00	0.00	0.05
Resident of PFN	0.13	0.13	0.00
Urban	0.01	0.10	0.07
Housing Characteristics	0.16	0.12	0.11
Garage	0.21	0.18	0.11
Job Status	0.12	0.12	0.10
Smoking Characteristics	0.19	0.20	0.14
Time Activity	0.18	0.23	0.17
Outdoor Concentration	0.04	0.09	0.04
Indoor Concentration	0.67	0.60	0.60

Table 41: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.07	0.11	0.11	0.04	0.02	0.03	0.03	0.02	0.02	0.00
Resident of PFN	-0.03	-0.07	-0.05	-0.11	-0.09	-0.04	-0.18	-0.21	-0.13	
URBAN	-0.10	-0.19	-0.20	-0.14	-0.15	-0.14	-0.13	-0.13		
TRAILOR	-0.07	-0.06	-0.05	-0.04	-0.02	-0.01	-0.05			
MULT2	0.00	-0.09	-0.09	-0.08	-0.07	-0.07	-0.09			
MED	0.04	0.09	0.11	0.12	0.10	0.12	0.08			
OLD	0.09	0.11	0.11	0.07	0.06	0.07	0.02			
NFCDAIR	-0.02	0.13	0.11	0.08	0.06	0.06	0.05			
CARET	-0.07	-0.06	-0.05	-0.03	-0.03	-0.01	0.02			
ATTG	0.05	0.26	0.25	0.22	0.24	0.27				
DETG	0.17	0.16	0.16	0.13	0.13	0.16				
UNPAVED	-0.00	-0.02	-0.03	-0.00	-0.01	0.00				
JOBFT	0.07	0.17	0.18	0.11	0.01					
JOBPT	-0.08	-0.07	-0.04	-0.06	-0.05					
SMKHOME	0.17	0.19	0.17	0.18						
SMKCAR	-0.13	-0.19	-0.20	-0.16						
SMKAMT	0.05	0.15	0.16	0.14						
SMKEXP2	-0.11	-0.16	-0.15	-0.15						
IH	0.13	0.19	0.19							
OH	0.01	-0.09	-0.09							
IW	0.07	0.02	0.00							
OW	0.03	-0.01	-0.02							
IA	0.09	0.07	0.06							
OA	-0.08	-0.10	-0.10							
T	0.09	0.09	0.10							
OCON3	0.04	0.10								
ICON3	0.67									
R	0.74	0.44	0.43	0.36	0.30	0.27	0.21	0.17	0.13	0.00

Figure 84: Results of Model of Personal Exposure to Octane

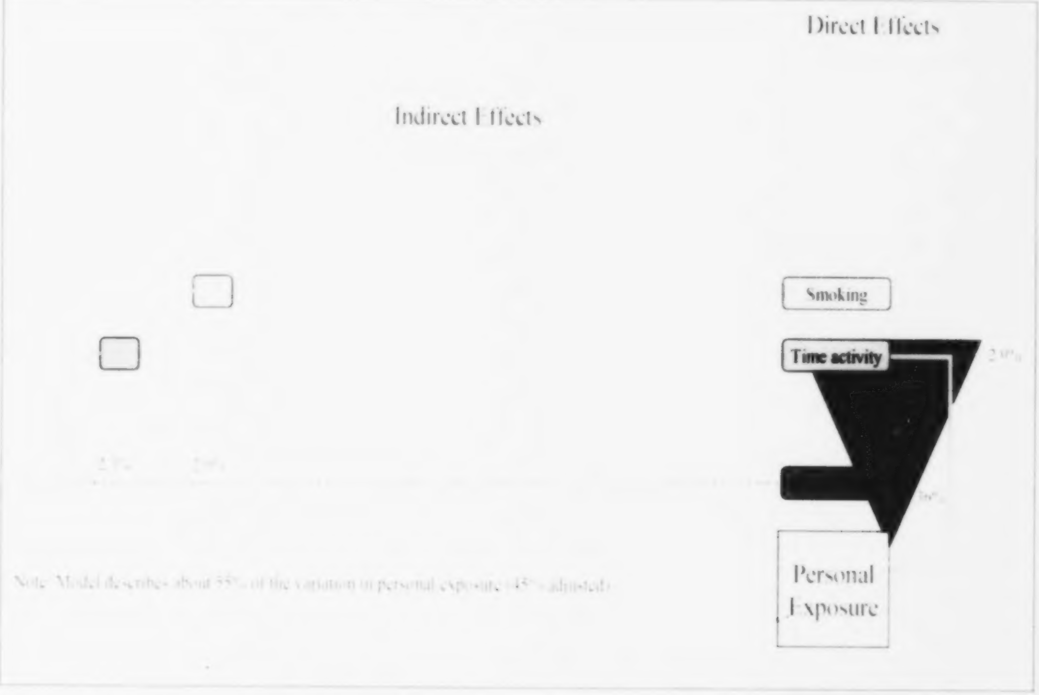


Note: Model describes about 55% of the variation in personal exposure (45% adjusted).

The model predicted about 55% of the variation (45% adjusted) in personal octane exposure across individuals and days. Important factors influencing the variations in octane exposure were as follows:

- ***Indoor levels***, directly (36%)
- ***Time Activity***, directly (2.9%) and indirectly (2.3%)
- ***Smoking***, operating indirectly indoor levels (2.0%)

Figure 84: Results of Model of Personal Exposure to Octane



Note: Model describes about 55% of the variation in personal exposure (45% adjusted)

The model predicted about 55% of the variation (45% adjusted) in personal octane exposure across individuals and days. Important factors influencing the variations in octane exposure were as follows:

- ***Indoor levels***, directly (36%)
- ***Time Activity***, directly (2.9%) and indirectly (2.3%)
- ***Smoking***, operating indirectly indoor levels (2.0%)

Nonane

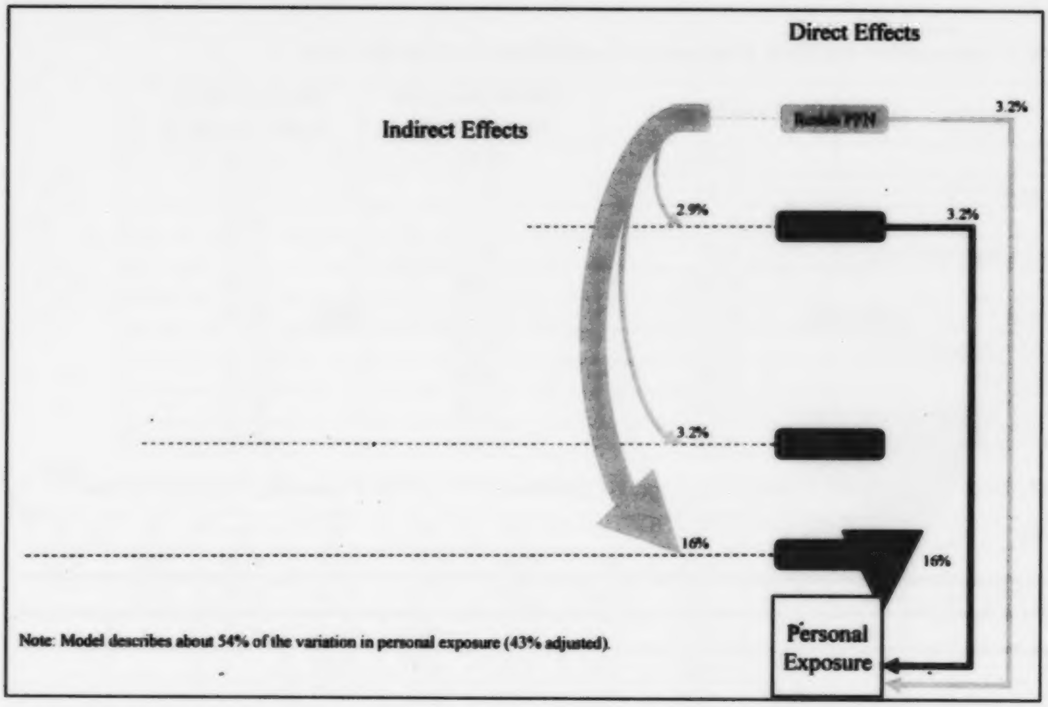
Table 42: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.03	0.03	0.06
Resident of PFN	0.50	0.50	0.18
Urban	0.25	0.04	0.03
Housing Characteristics	0.33	0.18	0.18
Garage	0.33	0.07	0.07
Job Status	0.07	0.17	0.13
Smoking Characteristics	0.34	0.17	0.10
Time Activity	0.29	0.13	0.14
Outdoor Concentration	0.12	0.12	0.04
Indoor Concentration	0.59	0.40	0.40

Table 43: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.09	0.13	0.12	0.10	0.10	0.10	0.10	0.10	0.10	0.04
Resident of PFN	-0.40	-0.62	-0.60	-0.64	-0.64	-0.57	-0.51	-0.54	-0.50	
URBAN	-0.05	-0.09	-0.05	-0.05	-0.07	-0.06	-0.05	-0.06		
TRAILOR	-0.17	-0.18	-0.19	-0.19	-0.17	-0.15	-0.13			
MULT2	0.02	-0.05	-0.06	-0.06	-0.04	-0.05	-0.04			
MED	-0.08	-0.07	-0.06	-0.05	-0.04	-0.02	-0.02			
OLD	-0.04	-0.03	-0.02	-0.01	-0.03	-0.00	-0.02			
NFCDAIR	0.07	0.13	0.13	0.12	0.11	0.11	0.13			
CARET	0.02	-0.01	-0.01	0.00	0.02	0.05	0.03			
ATTG	-0.11	-0.10	-0.13	-0.14	-0.11	-0.07				
DETG	-0.05	-0.11	-0.12	-0.15	-0.13	-0.10				
UNPAVED	-0.02	-0.06	-0.05	-0.04	-0.05	-0.04				
JOBFT	0.14	0.24	0.23	0.15	0.15					
JOBPT	-0.04	-0.05	-0.04	-0.08	-0.06					
SMKHOME	-0.01	0.04	0.04	0.06						
SMKCAR	0.01	0.03	0.04	0.03						
SMKAMT	0.02	0.01	0.01	0.01						
SMKEXP2	-0.11	-0.18	-0.18	-0.19						
IH	0.05	0.03	0.03							
OH	0.04	0.02	0.02							
IW	-0.04	-0.10	-0.11							
OW	-0.08	-0.03	-0.03							
IA	0.11	0.07	0.07							
OA	0.07	-0.01	-0.01							
T	-0.04	-0.01	-0.01							
OCON3	0.05	0.13								
ICON3	0.46									
R	0.73	0.61	0.60	0.59	0.56	0.54	0.53	0.50	0.50	0.04

Figure 85: Results of Model of Personal Exposure to Nonane



Note: Model describes about 54% of the variation in personal exposure (43% adjusted).

The model predicted about 54% of the variation (43% adjusted) in personal nonane exposure across individuals and days. Important factors influencing variations in nonane exposure were as follows:

- ***Indoor levels,*** directly (16%)
- ***Housing,*** directly (3.2%)
- ***Reside at Paul First Nation***, directly (3.2%)
- ***Reside at Paul First Nation,*** indirectly, operating on three factors:
    - Housing (2.9%)
    - Time Activity (3.2%)
    - Indoor levels (16%)

Figure 85: Results of Model of Personal Exposure to Nonane

Direct Effects
Indirect Effects
Reside PFN
Housing
Time activity
Personal Exposure
Note: Model describes about 54% of the variation in personal exposure (43% adjusted)

The model predicted about 54% of the variation (43% adjusted) in personal nonane exposure across individuals and days. Important factors influencing variations in nonane exposure were as follows:

- ***Indoor levels***, directly (16%)
- ***Housing***, directly (3.2%)
- ***Reside at Paul First Nation***, directly (3.2%)
- ***Reside at Paul First Nation***, indirectly, operating on three factors:
    - Housing (2.9%)
    - Time Activity (3.2%)
    - Indoor levels (16%)

Decane

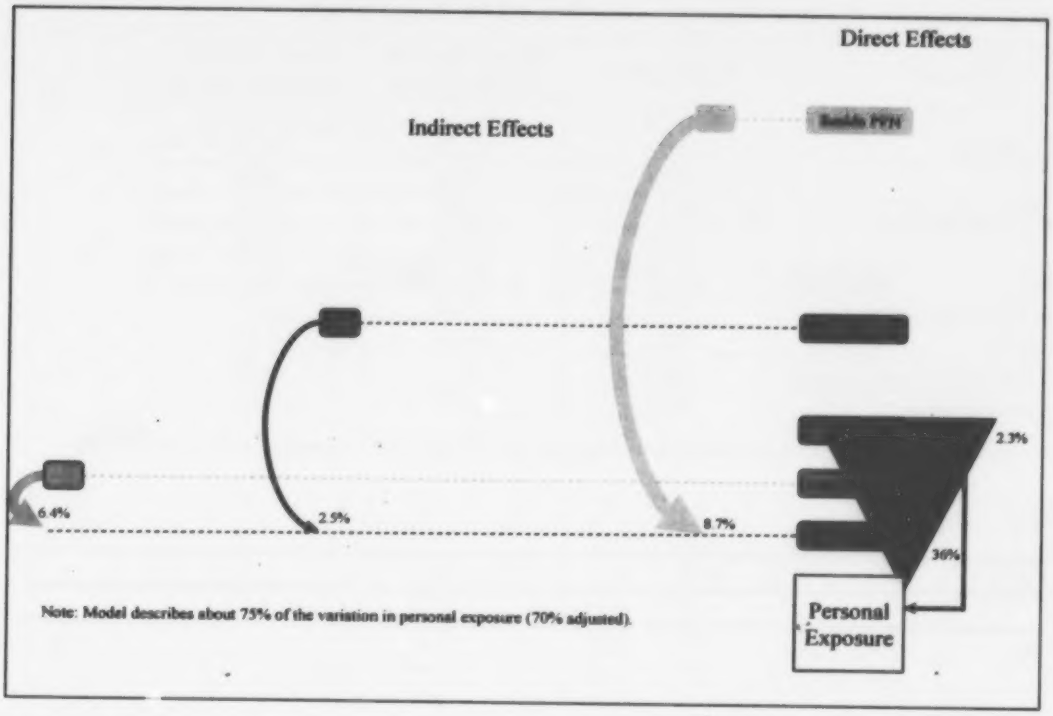
Table 44: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.00	0.00	0.06
Resident of PFN	0.37	0.37	0.05
Urban	0.10	0.13	0.05
Housing Characteristics	0.27	0.17	0.13
Garage	0.30	0.09	0.09
Job Status	0.17	0.22	0.09
Smoking Characteristics	0.27	0.18	0.13
Time Activity	0.24	0.19	0.15
Outdoor Concentration	0.21	0.28	0.12
Indoor Concentration	0.81	0.60	0.60

Table 45: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.07	0.10	0.10	0.07	0.06	0.07	0.07	0.06	0.05	0.01
Resident of PFN	-0.11	-0.43	-0.46	-0.46	-0.47	-0.39	-0.44	-0.47	-0.37	
URBAN	-0.08	-0.11	-0.12	-0.11	-0.11	-0.09	-0.12	-0.17		
TRAILOR	-0.05	-0.03	-0.03	-0.04	-0.02	-0.01	-0.03			
MULT2	-0.06	-0.13	-0.14	-0.12	-0.10	-0.11	-0.13			
MED	-0.03	-0.08	-0.01	-0.02	-0.03	0.00	-0.00			
OLD	0.05	0.06	0.03	0.02	0.01	0.04	0.04			
NFCDAIR	0.12	0.27	0.17	0.16	0.14	0.16	0.15			
CARET	-0.06	-0.12	-0.11	-0.08	-0.07	-0.03	-0.01			
ATTG	0.07	0.13	0.05	0.03	0.06	0.10				
DETG	0.12	0.14	0.08	0.03	0.04	0.07				
UNPAVED	0.03	0.06	0.04	0.07	0.07	0.09				
JOBFT	0.07	0.23	0.31	0.26	0.25					
JOBPT	-0.06	-0.01	0.11	0.10	0.11					
SMKHOME	0.15	0.22	0.18	0.16						
SMKCAR	-0.14	-0.13	-0.14	-0.13						
SMKAMT	-0.01	0.08	0.09	0.06						
SMKEXP2	-0.09	-0.18	-0.19	-0.16						
IH	0.05	0.04	-0.01							
OH	-0.06	-0.08	-0.07							
IW	0.05	-0.02	-0.09							
OW	0.02	0.05	0.04							
IA	0.08	0.06	0.05							
OA	-0.09	-0.16	-0.16							
T	0.06	0.02	0.07							
OCON3	0.15	0.34								
ICON3	0.70									
R	0.87	0.62	0.55	0.52	0.49	0.43	0.42	0.39	0.37	0.01

Figure 86: Results of Model of Personal Exposure to Decane

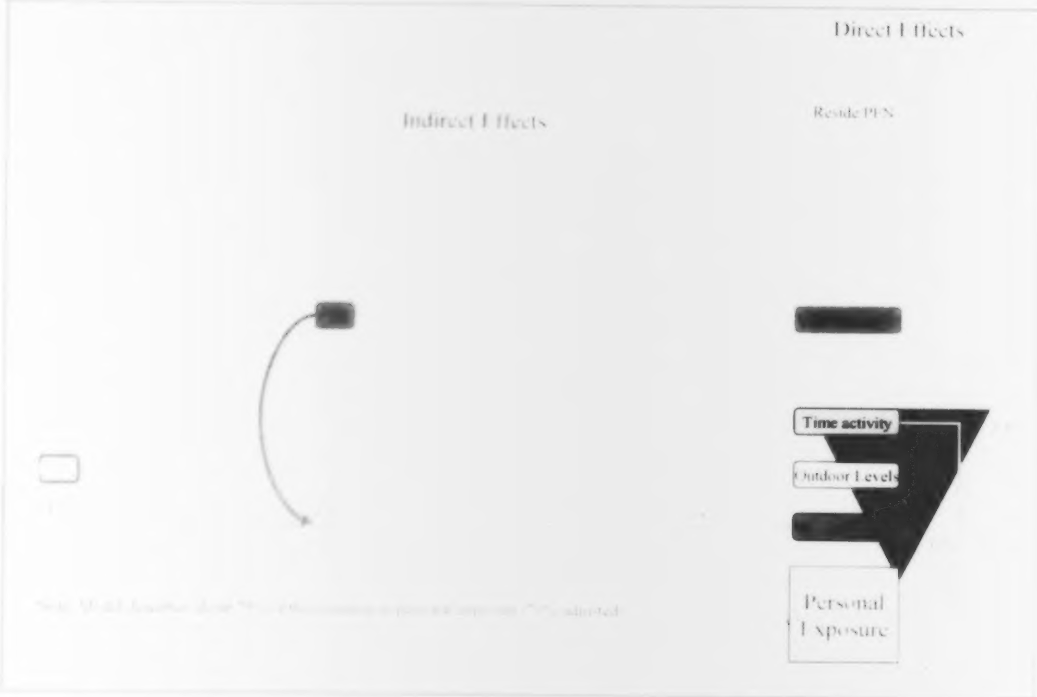


Note: Model describes about 75% of the variation in personal exposure (70% adjusted).

The model predicted about 75% of the variation (70% adjusted) in personal decane exposure across individuals and days. Important factors influencing variations in decane exposure were as follows:

- ***Indoor levels,*** directly (36%)
- ***Time Activity,*** directly (2.3%)
- ***Reside on Paul First Nation,*** operating indirectly on indoor levels (8.7%)
- ***Job Status,*** operating indirectly on indoor levels (2.5%)
- ***Outdoor levels,*** operating indirectly on indoor levels (6.4%)

Figure 86: Results of Model of Personal Exposure to Decane



The model predicted about 75% of the variation (70% adjusted) in personal decane exposure across individuals and days. Important factors influencing variations in decane exposure were as follows:

- ***Indoor levels***, directly (36%)
- ***Time Activity***, directly (2.3%)
- ***Reside on Paul First Nation***, operating indirectly on indoor levels (8.7%)
- ***Job Status***, operating indirectly on indoor levels (2.5%)
- ***Outdoor levels***, operating indirectly on indoor levels (6.4%)

N-propylbenzene

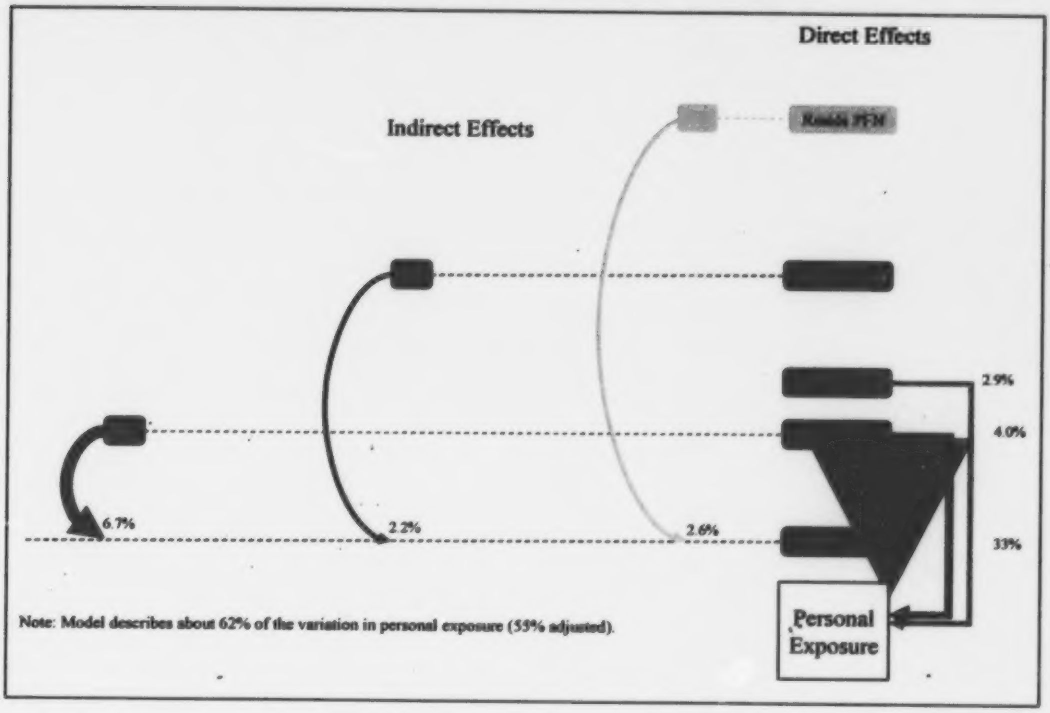
Table 46: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.10	0.10	0.13
Resident of PFN	0.25	0.23	0.08
Urban	0.05	0.09	0.09
Housing Characteristics	0.19	0.16	0.04
Garage	0.27	0.18	0.03
Job Status	0.09	0.11	0.11
Smoking Characteristics	0.22	0.18	0.17
Time Activity	0.32	0.33	0.20
Outdoor Concentration	0.05	0.11	0.00
Indoor Concentration	0.72	0.57	0.57

Table 47: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	0.16	0.20	0.20	0.13	0.13	0.13	0.13	0.14	0.13	0.10
Resident of PFN	-0.16	-0.29	-0.28	-0.32	-0.29	-0.26	-0.31	-0.30	-0.23	
URBAN	-0.14	-0.19	-0.15	-0.10	-0.11	-0.11	-0.12	-0.12		
TRAILOR	-0.02	-0.00	-0.01	-0.01	0.01	0.02	-0.01			
MULT2	-0.00	-0.04	-0.06	-0.05	-0.03	-0.03	-0.04			
MED	0.03	0.10	0.12	0.09	0.07	0.09	0.05			
OLD	0.00	0.05	0.07	-0.01	-0.02	-0.01	-0.09			
NFCDAIR	0.03	0.17	0.15	0.12	0.10	0.09	0.10			
CARET	0.00	-0.03	-0.02	0.01	0.02	0.03	0.06			
ATTG	-0.06	0.21	0.19	0.16	0.19	0.21				
DETG	-0.01	-0.00	-0.02	-0.04	-0.03	-0.01				
UNPAVED	-0.01	0.01	0.03	0.07	0.06	0.07				
JOBFT	-0.01	0.04	0.05	0.07	0.06					
JOBPT	-0.12	-0.16	-0.13	-0.09	-0.07					
SMKHOME	0.25	0.28	0.27	0.23						
SMKCAR	-0.16	-0.20	-0.20	-0.13						
SMKAMT	0.05	0.10	0.10	0.06						
SMKEXP2	-0.06	-0.12	-0.13	-0.11						
IH	0.10	0.13	0.11							
OH	-0.04	-0.14	-0.13							
IW	0.11	0.16	0.13							
OW	0.03	-0.05	-0.05							
IA	0.04	0.03	-0.04							
OA	-0.16	-0.25	-0.25							
T	0.08	0.15	0.20							
OCON3	0.00	0.13								
ICON3	0.68									
R	0.79	0.55	0.53	0.42	0.38	0.36	0.31	0.27	0.25	0.10

Figure 87: Results of Model of Personal Exposure to *N*-propylbenzene

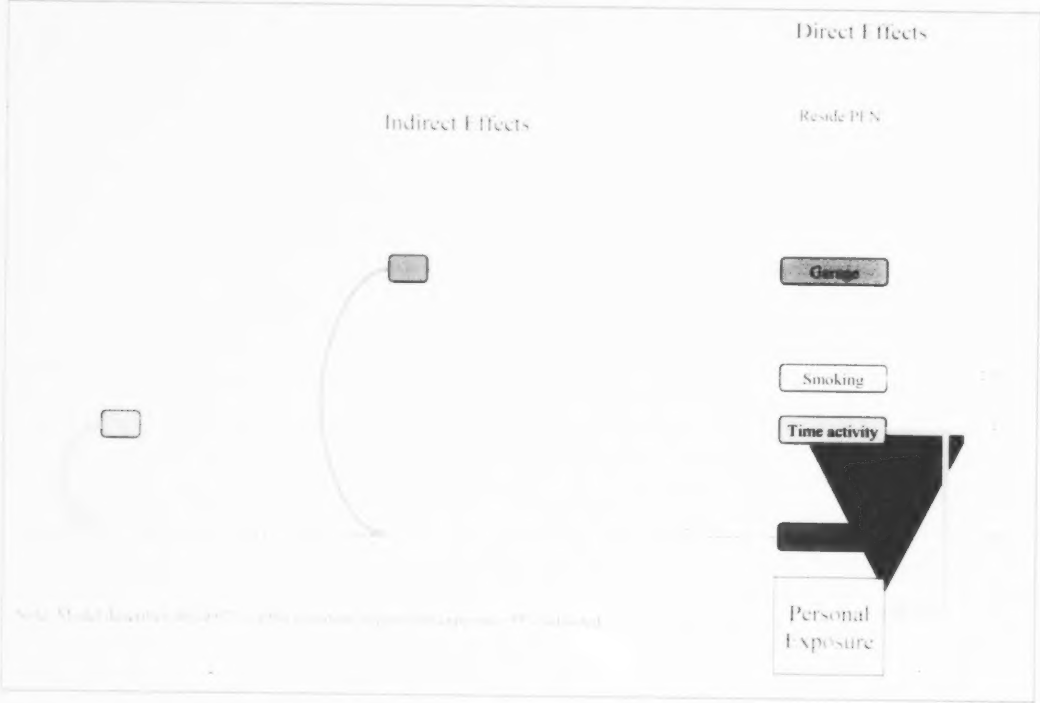


Note: Model describes about 62% of the variation in personal exposure (55% adjusted).

The model predicted about 62% of the variation (55% adjusted) in personal *N*-propylbenzene exposure across individuals and days. Important factors influencing variations in *N*-propylbenzene exposure were as follows:

- ***Indoor levels,*** directly (33%)
- ***Time Activity,*** directly (4.0%)
- ***Smoking,*** directly (2.9%)
- ***Reside on Paul First Nation,*** operating indirectly on indoor levels (2.6%)
- ***Garage,*** operating indirectly on indoor levels (2.2%)
- ***Time Activity,*** operating indirectly on indoor levels (6.7%)

Figure 87: Results of Model of Personal Exposure to N-propylbenzene



The model predicted about 62% of the variation (55% adjusted) in personal N-propylbenzene exposure across individuals and days. Important factors influencing variations in N-propylbenzene exposure were as follows:

- ***Indoor levels***, directly (33%)
- ***Time Activity***, directly (4.0%)
- ***Smoking***, directly (2.9%)
- ***Reside on Paul First Nation***, operating indirectly on indoor levels (2.6%)
- ***Garage***, operating indirectly on indoor levels (2.2%)
- ***Time Activity***, operating indirectly on indoor levels (6.7%)

8.8 Particulate Analysis: $PM_{2.5}$

The results of the analysis of relationships between personal exposures and the factors that may affect exposure are presented pictorially in Figure 88 after the supporting tables (Table 48 and 59). The model examined the relationship between the combined variability of all factors and the variation in personal exposure. The model accounted for 90% of the variation in personal exposure. However, because the sample size is very small for this analysis, there is greater uncertainty associated with these estimates (adjusted variation is only 54%). The unexplained variation in personal exposure is likely due to sampler error and other factors that were not included in the model.

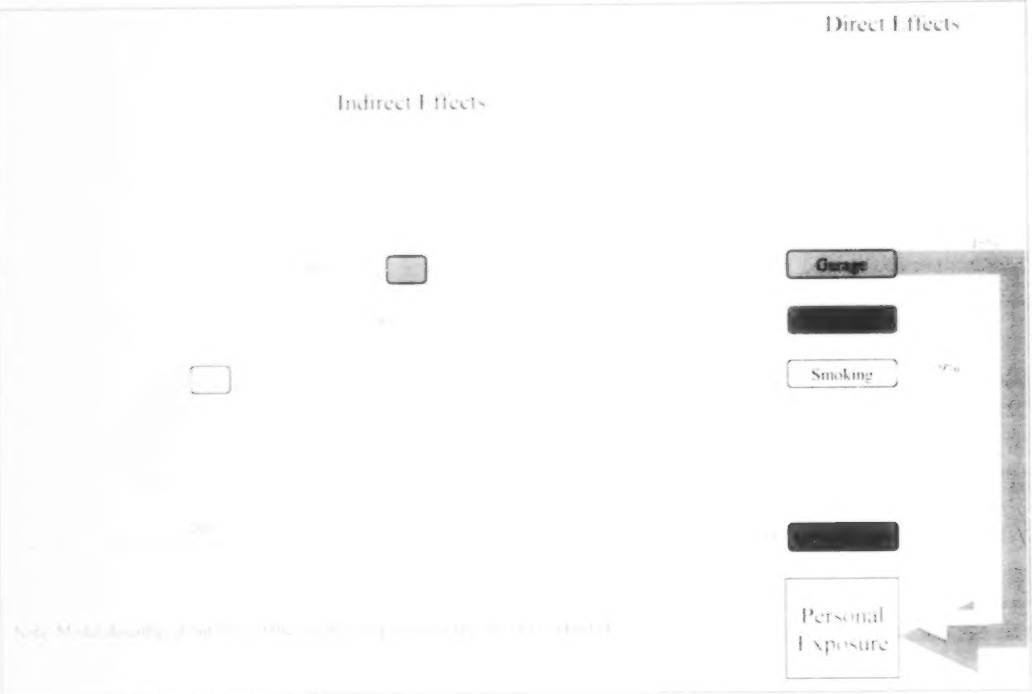
Table 48: Comparative Multiple Regression Coefficients for Variable Sets

Source	Total Effects	Model-Derived Total Effects	Direct Effects: Semi-Partial R
Gender	0.00	0.00	0.18
Resident of PFN	0.17	0.16	0.03
Urban	0.02	0.09	0.23
Housing Characteristics	0.29	0.28	0.22
Garage	0.52	0.54	0.39
Job Status	0.25	0.19	0.25
Smoking Characteristics	0.57	0.59	0.30
Time Activity	0.37	0.25	0.25
Outdoor Concentration	0.01	0.08	0.05
Indoor Concentration	0.60	0.04	0.04

Table 49: Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations

Source	Step 10	9	8	7	6	5	4	3	2	1
GENDER	-0.36	-0.38	-0.43	-0.22	-0.06	-0.08	0.03	0.03	0.03	0.02
Resident of PFN	-0.06	-0.08	-0.05	0.00	0.08	-0.02	0.20	0.20	0.17	
URBAN	0.54	0.52	0.54	0.39	0.39	0.44	0.08	0.10		
TRAILOR	0.00	0.00	0.00	-0.02	-0.15	-0.15	-0.05			
MULT2	0.49	0.53	0.51	0.35	0.14	0.03	0.04			
MED	0.03	0.01	0.02	0.01	0.07	0.12	-0.30			
OLD	-0.10	-0.12	-0.09	-0.05	-0.07	0.01	-0.17			
NFCDAIR	0.06	0.03	0.02	-0.03	0.17	0.22	0.05			
CARET	-0.29	-0.30	-0.27	-0.11	-0.10	-0.10	0.01			
ATTG	0.15	0.18	0.12	0.07	-0.42	-0.55				
DETG	0.57	0.61	0.56	0.56	0.05	-0.05				
UNPAVED	0.61	0.64	0.65	0.42	0.43	0.49				
JOBFT	-0.10	-0.07	-0.07	-0.20	-0.03					
JOBPT	-0.40	-0.38	-0.36	-0.31	-0.24					
SMKHOME	-0.00	0.01	0.02	0.25						
SMKCAR	0.48	0.55	0.54	0.25						
SMKAMT	0.16	0.18	0.13	0.18						
SMKEXP2	0.25	0.25	0.25	0.38						
IH	0.14	0.08	0.07							
OH	0.23	0.20	0.23							
IW	0.29	0.26	0.25							
OW	0.28	0.27	0.24							
IA	-0.00	-0.07	-0.06							
OA	-0.34	-0.38	-0.38							
T	0.21	019	0.19							
OCON3	-0.08	-0.11								
ICON3	0.11									
R	0.93	0.92	0.92	0.89	0.66	0.63	0.33	0.19	0.17	0.02

Figure 88: Results of Model of Personal Exposure to $PM_{2.5}$ Showing Direct and Indirect Effects of Factors



Important factors influencing variations in $PM_{2.5}$ exposures were as follows:

- ***Smoking characteristics***, operating indirectly through effects on indoor air (26%)
- ***Garage characteristics***, directly (15%)
- ***Garage characteristics***, operating indirectly through effects on job status (10%)
- ***Smoking characteristics***, directly (9%)

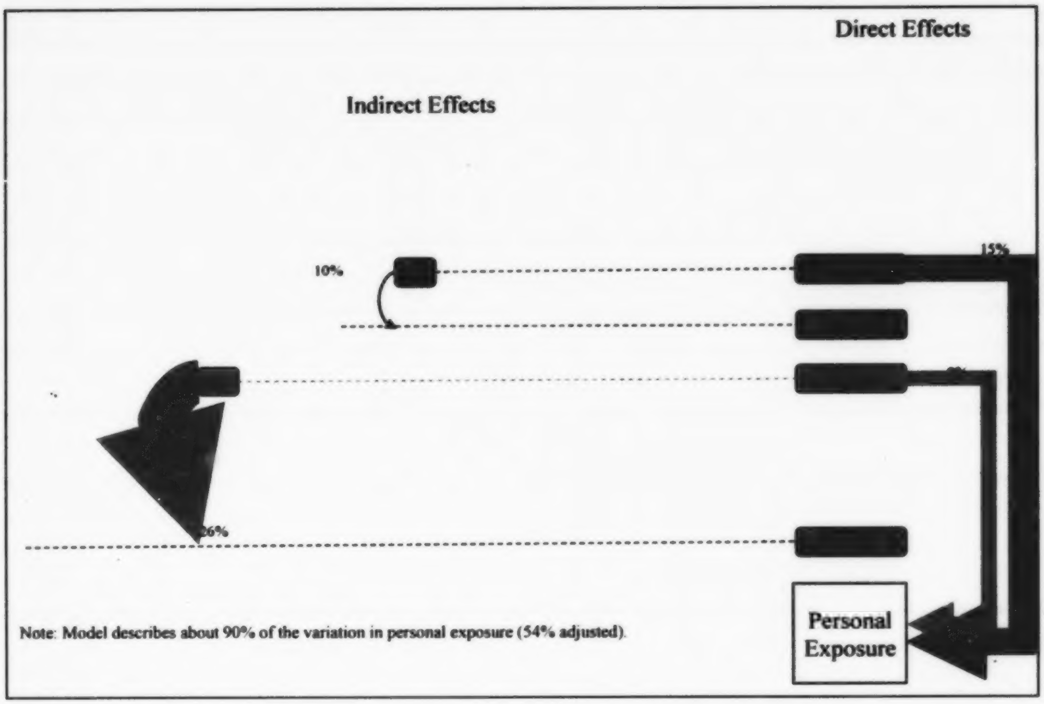
Variability in smoking operating directly and indirectly through indoor levels was the dominant factor affecting $PM_{2.5}$ exposure. Garage characteristics operating directly and indirectly through job status was also an important factor. Variations in outdoor concentrations were not associated with affecting personal exposure to $PM_{2.5}$.

Summary of Exposure Relationships for Passive Samplers

The previous sections have presented a large amount of information about a number of chemicals each analyzed separately. Within each analysis, careful examination of the tables can allow a sophisticated picture of causal influences to be postulated. However, little has yet been said about the manner in which the causal influences are similar across chemicals. In the following section, a higher order analysis is presented which can allow preliminary statements about the full domain of chemicals collected by passive samplers.

The starting point of this analysis is the regression coefficients for each of the independent variables included in the modeling process for each chemical. (These were presented in the column for the last step

Figure 88: Results of Model of Personal Exposure to $PM_{2.5}$ Showing Direct and Indirect Effects of Factors



Note: Model describes about 90% of the variation in personal exposure (54% adjusted).

Important factors influencing variations in $PM_{2.5}$ exposures were as follows:

- ***Smoking characteristics,*** operating indirectly through effects on indoor air (26%)
- ***Garage characteristics,*** directly (15%)
- ***Garage characteristics,*** operating indirectly through effects on job status (10%)
- ***Smoking characteristics,*** directly (9%)

Variability in smoking operating directly and indirectly through indoor levels was the dominant factor affecting $PM_{2.5}$ exposure. Garage characteristics operating directly and indirectly through job status was also an important factor. Variations in outdoor concentrations were not associated with affecting personal exposure to $PM_{2.5}$.

Summary of Exposure Relationships for Passive Samplers

The previous sections have presented a large amount of information about a number of chemicals each analyzed separately. Within each analysis, careful examination of the tables can allow a sophisticated picture of causal influences to be postulated. However, little has yet been said about the manner in which the causal influences are similar across chemicals. In the following section, a higher order analysis is presented which can allow preliminary statements about the full domain of chemicals collected by passive samplers.

The starting point of this analysis is the regression coefficients for each of the independent variables included in the modeling process for each chemical. (These were presented in the column for the last step of the set of tables entitled, "Beta Weights for Hierarchical Set Regression of Personal Exposure Concentrations" for each analysis of personal exposure). Basically, these numbers were brought together into a single table (with a separate column for each chemical and separate row for each set of influences) for the current analysis.

Next, a principal component decomposition of this table was performed, and the largest two dimensions of this analysis were used for a single biplot representation displayed in Figure 89. With proper interpretation, this diagram summarizes the information present in the original table (to a substantial degree, though more dimensions would be required to allow complete reconstruction). The advantage of this analysis is that it can represent the relative importance of the causal influences across chemicals, and the relative similarity of chemicals with respect to their causal influence structure within a single graphic representation.

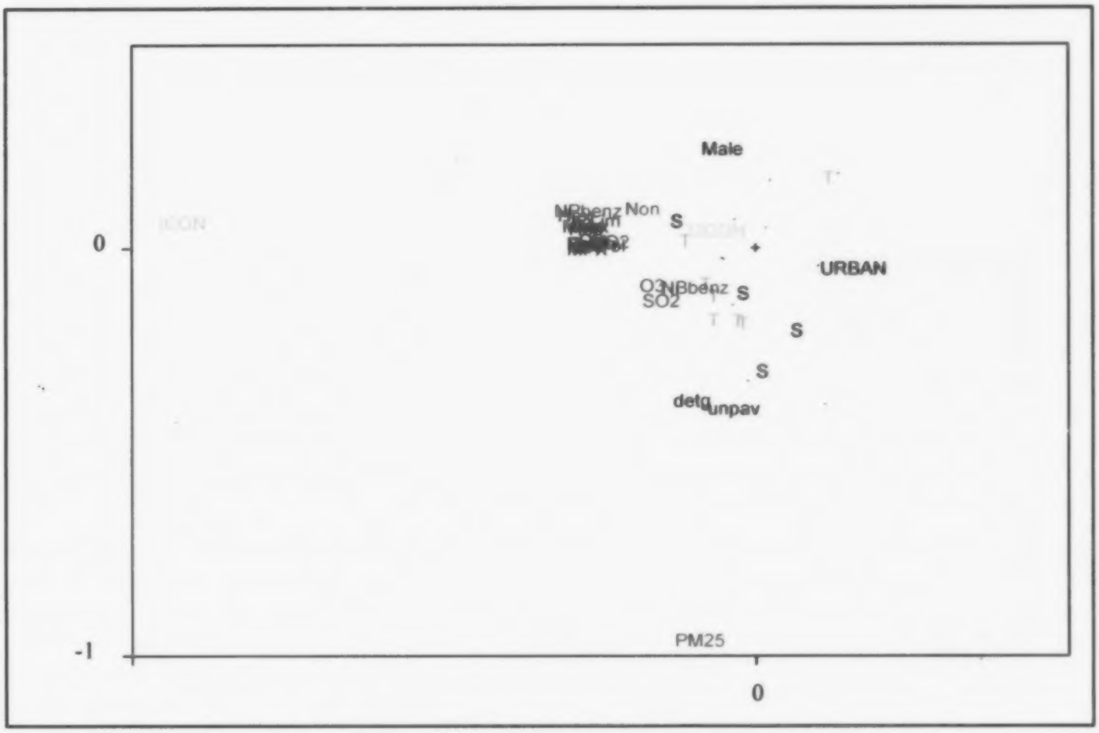
The interpretation of this diagram is as follows: each causal influence and each chemical has a coordinate in the two dimensional space. In absolute terms, the average size of the semi-partial multiple correlation coefficients across all chemicals considered together can be determined by the relative location of the points representing the causal influences on the first dimension. That is, the orderings of the coefficients on the first dimension gives the average ordering of the coefficient across all chemicals. In the current case, it can be seen that the influence of indoor concentrations is the single largest influence on the personal concentrations across this set of chemicals (because it has the highest positive value on the first dimension; it is located to the extreme right).

The inclusion of the second dimension on each of the diagrams allows chemicals to be separated based upon differences in the pattern and magnitude of the set of influences. To determine the nature of these differences, follow this basic procedure for each chemical point: mentally draw a line from its co-ordinate through the '+' located on the graph at the 0,0 point (the origin). Consider this line as a new dimension. Values of the causal influences are ordered on this dimension in terms of their order of magnitude in predicting the concentration of that chemical. (Mentally, the operation to determine the values of the influences on this new dimension requires that you draw a perpendicular line from the point to the new point to the axis dimension (technically, "orthogonally project"). This operation is entirely analogous to determining the value of a point on a labelled dimension, as was necessary to determine the magnitudes (described above). Notice that the actual pattern and ordering of the influences will differ for chemicals located in different quadrants of the space.

The analogous procedure can be performed for each set of influences to derive an ordering of chemicals for which this set of influences is relatively more or less important.

Finally, a global mode of interpretation is possible by combining all of this information as follows: chemicals in the same radial sector have similar patterns of influence, those farther from the origin (the '+' point) are more predictable than those nearer the origin. For personal concentration levels, this pattern is shown by SO_2 and O_3. Chemicals that are close together on the plot have similar patterns of influence and similar levels of predictability. For personal concentrations, this condition is clearly met for the VOCs.

Figure 89: Biplot Representation of Semi-Partial R for Determinant Sets of Chemicals (Personal Concentrations)



The overall impression that is left by this global mode of interpretation is as follows:

- For all VOCs, indoor levels are the most important causal feature
- Outdoor concentrations are relatively more important for SO_2, O_3 and *N*-butylbenzene than for NO_2 and other VOC
- Time-activity patterns and smoking behavior are relatively more important for SO_2, O_3, and NO_2 than for (most of) the VOCs
- $PM_{2.5}$ has a distinctly different pattern where smoking variables and particularly having an attached garage and an unpaved drive are major predictors of exposure

9.0 Biomarkers of Exposure

A biomarker of exposure is a chemical and/or its metabolites which can be quantitatively identified in a biological system or in samples such as biological fluids, tissues and expired air. Blood and urine samples were collected to measure some biomarkers of exposure: nicotine, mercury, arsenic, and four metabolites related to exposure to benzene, toluene, ethylbenzene and xylene.

9.1 Nicotine

Background

The optimal assessment of exposure to tobacco smoke is to analyze the concentrations of a component of smoke in the body fluids of an exposed individual. Nicotine is such a chemical and is found in all tobacco products. Therefore, it can act as a biomarker of exposure. A cigarette smoker inhales about 1 mg of nicotine per cigarette smoked.[42,43,44] Over 75% of the nicotine is emitted into the air as sidestream smoke; the remaining portion enters the blood via the lungs and is circulated to other body organs such as the liver and kidneys. There it is then converted into several metabolites, 70% to 80% of nicotine is converted to cotinine and 5% to 10% unchanged nicotine is excreted in the urine.[45]

Results

A total of 165 adults completed the questionnaire portion regarding smoking practices and provided blood samples for nicotine analysis. The information on smoker status is summarized in Table 50. In the questionnaire survey, 39% of all the participants were active tobacco smokers, 16% are exposed to second-hand smoke, and 43% were non-smokers. Four (4) participants (2%) did not provide any information regarding their exposure to tobacco smoke. Nicotine was detected in 40 of the 165 (24%) participants with the average level of nicotine being 4.0 ng/mL. Of these 40 participants, 90% of the participants indicated they were active smokers and 5% were non-smokers. The remaining 5% of participants did not provide any information on their smoking status. Nicotine was not detected in 27 of the 64 (42%) participants who reported themselves as active smokers and in 26 participants who indicated they were exposed to second-hand smoke.

The results indicated that the measurement of nicotine concentrations in blood could be used to assess exposure to active tobacco smoke. However, as nicotine only stays in blood for about 2-3 hours[46], it is not entirely predictive of individuals who may be exposed to tobacco smoke.

Table 50: Self-Reported Smoker Status and Detection of Nicotine

	Self Reported Smoker Status (N=166)*				**Detection of Nicotine (N=40)**		
	Active Smoker	**Exposed to second-hand smoke**	**Non - smoker**	**Not reported**	**Active Smoker**	**Non - Smoker**	**Not reported**
Number of participants (% of total)	64 (39%)	26 (16%)	72 (43%)	4 (2%)	36 (90%)	2 (5%)	2 (5%)

**Note: These results represent all participants who completed this portion of WACEHEAP.*

9.2 Mercury

Background

Mercury occurs naturally in the environment in three different forms: elemental mercury, inorganic mercury and organic mercury. It occurs naturally as the result of the normal breakdown of minerals in rocks and soil from exposure to wind and water, from forest fires and volcanic activity. Mercury can also be released into the environment by human activities such as mining, burning of coal from power plants, and the production of cement. Of the three forms, elemental mercury is released the most in the air from human activities and is of most concern. Methyl-mercury (organic mercury) is often formed from other forms of mercury during microorganisms and natural processes in the water. Methyl-mercury can accumulate in the tissues of some fish, which can contribute to higher mercury levels for fish consumers.[47]

Individuals are exposed to very low levels of mercury in the air, water and food. Mercury levels in the air are very low (10 to 20 ng/m^3) in the urban area.[48] A potential exposure to elemental mercury for the general population is from dental amalgam fillings. Some people may be exposed to higher levels of methyl-mercury from eating fish from mercury-contaminated fresh water and sea. To assess an individual's exposure, total mercury levels can be determined from three types of biological samples: blood, urine and hair. Total mercury levels include inorganic (elementary mercury which has been metabolized by the body) and organic mercury (methyl-mercury). It is important to note that total blood mercury and total hair mercury is 80% methyl-mercury.

Blood and hair samples are used as an indication methyl-mercury exposure in people who eat fish *without* significant exposure to inorganic mercury or elemental mercury.[49] Total hair mercury is not an accurate exposure indicator compared to total blood mercury because potential external sources (e.g. mercury from the air) and many confounders (e.g. use of shampoo and different rates of hair growth) can affect mercury levels in hair.[50] Of the three samples taken, total urine mercury is the better indicator of mercury exposure as it best reflects exposure to elemental mercury in an inorganic state.

Results

A total of 165 adults provided blood samples, 163 adults provided urine sample, and 164 adults provided hair samples. The average amount of total mercury was 1.4 µg/L in blood, 0.64 µg/L in urine, and 0.22 µg/g in hair. The mean levels of total mercury in this analysis were similar to the levels of 1-8 µg/L in whole blood and lower than the levels of 4-5 µg/L in urine in the general population reported in the literature.[51,52,53,54,55] From studies conducted approximately 20 years ago, the levels of hair mercury in the U.S. general population ranged from 0.47 to 3.8 µg/g.[56] The levels detected in WACEHEAP participants were lower however it should be noted that mercury levels in hair may have decreased in recent years but have not been reported in scientific literature. In addition, total mercury in hair can be affected by many confounding factors and is not believed to be representative of exposure.

The mercury levels measured in blood, hair and urine from WACEHEAP participants indicated that local residents were exposed to very low levels of mercury from the surrounding environment such as air, water and food, and that the exposure levels were similar to those in the general population living in other areas.

9.3 Arsenic

Background

Arsenic is widely distributed in nature as organic or inorganic forms. Inorganic arsenic is usually found in the water, soil and air. In water sources, groundwater normally contains higher concentrations of inorganic arsenic than surface water sources such as rivers or lakes. Organic arsenic is usually found in plants, animals and most food.

People ingest small amounts of arsenic (about 50 micrograms) everyday from the foods they eat, particularly shellfish and water. Sometimes people may inhale arsenic by breathing in smoke from burning arsenic contaminated materials like treated wood. Higher levels of arsenic may be ingested by those who use groundwater for their drinking water supply. Once arsenic enters the body, the liver changes some to a less harmful form and it leaves blood within a few hours. Within several days most of the arsenic leaves the body in our urine, although some will remain in the body for several months or longer.

Blood arsenic is not a reliable biomarker of exposure because of the short duration in the blood.[57] The level of arsenic in urine is a reliable biomarker of exposure in populations living near industrial point sources. Many studies use a urinary level of greater than 100 μg Total As/L as evidence of recent arsenic ingestion.[58,59,60,61] The concentration of the total urinary arsenic is not well correlated with the concentrations of inorganic arsenic in the environment as total arsenic contains high levels of organic trimethylarsenic (TMA) from dietary sources of marine origin such as arsenobetaine and arsenocholin.[62,63,64] Urinary arsenic speciation may indicate the extent of past exposure as well as current exposure to inorganic arsenic.[65] Inorganic arsenic compounds such as Arsenic III and IV are converted in the body to monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA). MMA and DMA are excreted in the urine within three days after exposure. The proportion of arsenic species in the urine is usually 60%-80% DMA, 10%-20% MMA and 10%-20% inorganic arsenic.[66,67]

Results

A total of 165 adults provided blood samples and 163 provided urine samples for arsenic analysis. An average level of total arsenic was 0.37 μg/L in blood which is lower than the mean level of blood arsenic reported in the literature of <1 μg/L.[68] In Table 51, the mean concentration of arsenic in urine from different studies is provided. Urinary arsenic levels are known to vary in the general population by geographical regions, depending on differing levels of arsenic in drinking water. As compared to urinary arsenic levels from U.S. and European populations, the means of these compounds were lower in our participants.

Table 51: Mean of Urinary Arsenic Species (μg/L) in Different Studies

Program/Relevant Literature	Location	Sample Size.	Total As	As III+ AS V	DMA	MMA
Wabamun (2004)	Alberta, Canada	163	6.0	0.59	3.9	0.5
Fort McMurray (2000)	Alberta, Canada	131	5.2	0.8	2.9	0.5
Kalman et al.[69] (1990)	U.S.	696	9.2	1.3	6.4	1.6
Kurttio et al.[70] (1998)	Finland	9	5.0	2.0	5,0	0.8

9.4 Benzene

Background

Benzene is a colorless liquid and evaporates into air very quickly and dissolves slightly in water. Natural sources include volcanoes and forest fires. Major man-made sources of benzene in the environment for the general population come from petroleum processes and products (e.g. motor vehicle exhaust, emission from burning coal and oil and evaporation from gasoline service station) and tobacco smoke. The general population is exposed to a small quantity of benzene everyday through consumption of food and drinking water. However, the major route of exposure is through inhalation and accounts for 99% of the exposure in the general population.[71] Half of the benzene inhaled is absorbed in the blood stream, and the remaining portion is exhaled.

While benzene can be temporarily stored in the bone marrow and fat, it is converted by the body into metabolites, such as *t,t*-muconic acid (*t,t*-MA).[72] Urinary *t,t*-MA can be used as an indicator of acute exposure to benzene. While most of the metabolites leave the body through the urine within 48 hours, from inhalation, *t,t*-MA represents 1% to 4% of dose[73] and has a half-life of elimination of approximately 5 hours[74]. Urinary, *t, t*-MA can be affected by tobacco smoke and dietary intake especially consuming foods where sorbic acid is present.[75]

Results

A total of 163 adult participants provided urine samples for *t,t*-MA analysis. An average level of *t,t*-MA was 0.17 mg/g Cr. The background levels of *t,t*-MA reported in the literatures ranged from 0.02 to 0.69 mg/g Cr in the general population.[76,77,78,79,80,81,82,83,84,85,86]

The measured *t,t*-MA levels only reflect a small amount and short term exposure (a few hours) to benzene from the environment. The results indicated that local residents were exposed to a low level of benzene similar to populations living in other areas. This low level exposure could be from exposure to motor vehicle exhaust, emission from gasoline service stations and tobacco smoke.

9.5 Toluene

Background

Toluene is a clear, colorless, volatile liquid with an aromatic smell. Natural sources include crude oil, coal and the tolu tree but it is added to gasoline along with benzene and xylene. It is also present in many industrial and household products such as solvents for making paints, paint thinners, fingernail polish, adhesives and rubber. Toluene is released into the air from these products and from gasoline usage, especially vehicle exhaust. Soil and water can be contaminated from nearby waste sites. The general population is mainly exposed to toluene from vehicle exhaust or tobacco smoke with exposure from drinking water and food source is insignificant.

Urinary hippuric acid (HA) is a major metabolite of toluene[87] but is not very specific to toluene exposure, particularly at low levels of exposure.[88,89,90] HA levels were affected by genetic factors, sex, alcohol consumption, beverage consumption and smoking.[91,92,93,94.95] Other chemicals such as ethylbenzene, styrene and benzoic acid can also affect HA levels.[96]

Results

A total of 163 adult participants provided urine samples for HA analysis. The average level of HA detected was 0.78 g/g Cr (0.5 g/L). The background levels of HA reported in the literatures ranged from 0.16 to 0.35 g/g Cr in the general population.[97,98,99,100,101] In occupational studies directly related to toluene exposure, the HA levels were about 2 g/g Cr if workers were exposed to a high level of toluene (>115 ppm).[102] When exposure levels of toluene are less than 800 pm, HA is not a good indicator to accurately exam toluene exposure.[103] HA levels in the body could be influenced by individual variability, tobacco smoke, alcohol consumption, and consumption of beverages (coffee, soy been milk and juice), fruits (cranberries and plum) and food (bread with food preservatives). These types of food and beverage in particular contain benzoic acid which can increase HA levels in urine.[104]

9.6 Ethylbenzene

Background

Ethylbenzene is a colorless liquid which smells like gasoline and occurs naturally in coal tar and petroleum. It is present in gasoline (2% by weight), tobacco, carpet glues, paints, inks, insecticides, asphalt, naphtha, fuels and in the manufacturing of styrene. By burning oil, gas and coal, ethylbenzene is commonly found in the air but can breakdown in less than three (3) days in the environment. People can be exposed to ethylbenzene from inhalation if they live close to heavy traffic and industrial areas. Ethylbenzene concentrations in indoor air are higher than those in outdoor air because it accumulates in indoor environments by using household products such as cleaning products and paints, and from tobacco smoke.

Ethylbenzene enters the human body through inhalation or skin contact and is excreted in the urine within two (2) days. Mandelic acid (MA) is one of the metabolites which can be measured in urine. The recommended biological exposure index in workplace is 1.5 g/g Cr of MA in urine.[105] The background levels of MA ranging from 2.6 to 5 mg/L or 1.3 mg/g Cr.[106]

Results

A total of 163 participants provided urine samples for MA analysis. MA was not detected in any samples. Therefore, local residents were not exposed to measurable levels of ethylbenzene from the environment.

9.7 Xylene

Background

Xylene is a colorless liquid with a sweet odor and is primarily a synthetic chemical produced from petroleum. It occurs naturally in petroleum and coal tar or is formed during forest fires. Xylene is used along with other solvents in household products such as cleaning agents, thinner for paints, in varnishes and in the coating of fabrics and papers. As xylene evaporates easily and enters into the air, people are mainly exposed to it by inhalation. Inhalation sources include automobile exhaust, using consumer products such as tobacco, gasoline, paint, and varnish and rust preventives. People are also exposed to xylene by drinking water and skin contact with solvents, paint thinners and removers, and pesticides.

Xylene is metabolized into other chemicals in the liver and excreted via the urine. Methylhippuric acid (MHA) in the urine is the primary biomarker used to detect xylene exposure.[107,108] MHA is excreted in the urine within 1 or 2 days of exposure to xylene. The recommended biological exposure index in workplace is 1.5 g/g Cr of MHA in urine.[109] The median background concentrations of o-MHA range from 7.5 mg/L or 2 - 8.5 mg/g Cr.[110,111]

Results

A total of 163 participants provided urine samples for MHA analysis. Similar to HA, MHA was not detected in any urine samples. The results indicate that local residents were not exposed to measurable levels of xylene from the environment.

9.8 Summary

A summary results table of the biomarkers of exposure is provided in Table 52. Nicotine was detected in the blood in some participants who reported themselves as active tobacco smokers. Mercury, arsenic and two metabolites related to benzene and toluene exposure were detected in blood and/or urine samples. The measured levels of these biomarkers were similar to the background levels in the general population living in other areas. Two metabolites related to ethylbenzene and xylene exposure were not detected. Overall, the results demonstrate that residents of the WACEHEAP area are exposed to very low levels of the selected chemicals.

Table 52: Means and Ranges of Measured Biomarkers of Exposure in Adults

Biomarker	Type	Sample Size	Unit	Mean	Min	Max	Potential Exposures
Nicotine	Urine	165	ng/ml	4.0	N/D*	37.6	Active tobacco smoke (very short term)
Total Mercury	Blood	165	µg/L	1.4	N/D	11.8	Methyl-mercury exposure such as fish consumption
	Hair	164	µg/L	0.2	N/D	1.9	
	Urine	163	µg/L	0.6	N/D	3.7	Inorganic mercury exposure such as dental amalgam
Total Arsenic	Blood	165	µg/L	0.4	N/D	7.0	Very short term exposure
	Urine	163	µg/L	6.0	0.24	91	
Arsenic III	Urine	163	µg/L	0.09	N/D	1.8	Mainly from water, specifically ground water
Arsenic V			µg/L	0.5	N/D	8.0	
Dimethylarsenic			µg/L	3.9	N/D	107	
Monomethylarsenic			µg/L	0.5	N/D	19	
Muconic acid (Benzene)	Urine	163	mg/g Cr**	0.17	N/D	2.4	Mainly from motor vehicle exhaust, tobacco smoke, emission from gas station, or household products HA can also be affected by food and beverage consumption
Hippuric acid (Toluene)	Urine	162	g/g Cr	0.78	N/D	2.7	
Methylhippuric acid (Xylene)	Urine	163	mg/g Cr				
Mandelic acid (Ethylbenzene)	Urine	163	mg/g Cr				

**N/D = not detected*

***Cr: Creatinine – adjusted concentration in order to correct variation of urination volume*

10.0 Biomarkers of Effect

A biomarker of effect is any change that can be predictive of a health impairment or potential impairment resulting from exposure to any air contaminant. In the Wabamun and Area Community Exposure and Health Effects Assessment Program (WACEHEAP), three different biomarkers of effect were measured: (1) serum immunoglobulin gamma (serum IgE) in the blood to estimate the impact to human health from natural sources such as pollen and dust to determine impacts from industrial activity; (2) the prevalence of autoantibodies in participants' blood samples which can be compared against reference samples to determine differences in exposure and response by elevated immune system reactions and (3) an evaluation of lung function to see if respiratory health of the participants has been affected by exposure to air contaminants.

10.1 Immunoglobulin gamma E (IgE)

Background

Immunoglobulin gamma E (IgE) is an excellent marker for allergic (atopic) reactions including asthma, hay fever, anaphylaxis and eczema. High levels of IgE are associated with increased prevalence and severity of asthma[112,113,114] and bronchial hyper-responsiveness.[115] Asthma rates are related to serum IgE levels even in subjects with negative skin test reactivity.[116]

Allergen priming begins *in utero*. Several studies now indicate that patterns of immune deviation in the first year of life determine atopic status in later years.[117] For example house dust mite specific T-cells have been identified in cord blood.[118] Sensitization to allergens is age dependent reaching its peak in late childhood.[119] While total serum IgE generally declines with age[120,121,122] and is also influenced by race[123,124] smoking history[125], occupation[126,127] exposure to aero-allergens [128,129] and gender.[130,131] There is evidence that environmental agents, particularly diesel exhaust particulates and cigarette smoke, are capable of enhancing IgE immune responses.[132,133] The relationship between serum IgE and age is different for men and women. For women, IgE levels fall with age whereas in men IgE levels remain relatively stable.[134] Studies have also shown an inverse relationship between serum IgE and rate of decline in forced expiratory volume (FEV_1) [135,136,137,138] a measure of lung function. After allowing for age and gender, serum IgE and smoking interact synergistically as risk factors for airflow obstruction.[139]

The number of IgE specific antibodies to inhalant allergens is also a risk factor for emergency room visits for asthma.[140] Specific IgE is related to age[141,142] smoking[143], and occupational exposures.[144] Like total IgE, specific IgE declines with age.[145,146] Specific IgE antibodies to food or inhalant allergens in wheezing infants are highly predictive of subsequent development of asthma.[147]

In this program, serum samples from participants in the Wabamun and surrounding area were assayed for total and specific IgE. The results were correlated with demographic factors and pulmonary function and compared with previous CEHEAP studies including those in Fort Saskatchewan, Grande Prairie, Fort McMurray and Lethbridge.

Total Serum IgE

The mean and log transformed values of IgE in the serum of the adult participants are shown in Table 53.

Table 53: Total Serum IgE Results

	Raw Data (kU/L)	Log Transformed Data (kU/L)
Mean	53.733	1.201
Median	16.00	1.204
SE	10.099	0.053
SD	129.725	0.682
N value	165	165

The distribution of total IgE can be divided into four categories: (1) low level (less than 20); (2) intermediate level (20-99); (3) high (100-399) and (4) very high (more than 400) kU/L. This is shown in Table 54. For 19 participants or 11.5% an elevated IgE level was detected. An elevated IgE level is total serum level above 100 kU/L.

Table 54: Distribution of Total Serum IgE

Category	IgE (kU/L)	Percent (%)
Very high	>400	3.0
High	100-399	8.5
Intermediate	20-99	33.3
Low	<20	55.2

Specific IgE – Ingestant Screen

Table 55 shows the response to the ingestant screen for all participants. An ingestant allergen screen is a food mix that detects allergens to one or more of the following: milk, egg white, wheat, soy, peanut and codfish. Only six (6) individuals had a positive response and those scores are provided in the appendices (see Appendix B) of this report. Those with a positive response had significantly greater IgE level than the 159 participants with a negative response (p = 0.011). The median IgE for the positive responders was 82.0 kU/L compared with a median of 15.0 kU/L in those with a negative ingestant screen.

Table 55: Ingestant Screen Results

	Positive Response (Log data)	**Negative Response (Log data)**		**Positive Response (Raw data)**	**Negative Response (Raw data)**
Mean ± SE	1.989±0.262	1.171±0.053	Median	82.0	15.0
n-value	6	159		6	159
Statistically significant*	0.011		Statistically Significant*	0.011	

**Mann-Whitney Rank test*

Specific IgE – Inhalant Screen

Table 56 shows the inhalant screen for all participants. The inhalant allergen screen (Phadiotop test) is a mixture of allergens which detects IgE antibodies to the following: timothy grass, dandelion, silver birch, cat dander, dog epithelium, horse dander, rye and two molds – *Alternaria tenuis* and *Cladosporium pteronnyssinus.* Thirty-four (34) individuals had a positive response, whereas 131 had a negative response. Again, the median IgE in the positive responders was significantly greater than those in the negative responders ($p < 0.001$). For those with positive inhalant screens, follow-up tests were done and those results are provided in the appendix for this section.

Table 56: Inhalant Screen Results

	Positive Response (Log data)	**Negative Response (Log data)**		**Positive Response (Raw data)**	**Negative Response (Raw data)**
Mean ± SE	1.771±0.095	1.053±0.055	Median	50.5	12.0
n-value	34	131		34	131
Statistically significant*	<0.001		Statistically Significant*	<0.001	

**Mann-Whitney Rank test*

Characteristics of the Wabamun sample such as age, gender, smoking status, having asthma and being a member of Paul First Nation were examined versus log IgE results. These calculated results are provided in the appendices of the report and should be reviewed in context of statistical significance. In summary, participants who had ever smoked, especially those who are current smokers had high IgE levels. Also participants who were members of Paul First Nation, had doctor confirmed asthma or those who reported wheezing near trees had statistically significantly elevated serum IgE levels compared to those who did not. Characteristics such as having a pet in the home; whether the mother smoked during pregnancy or birth order do not affect serum IgE levels.

Lung function measured as forced vital capacity (FVC) and forced expiratory volume (FEV_1) percent of predicted was determined for certain characteristics. These calculated results are provided in the appendices of the report and should be reviewed in context of statistical significance. Significant negative relationships were seen between FVC and FEV_1 with a history of asthma, being a Paul Band participant and being born in Alberta ($p = 0.03$). Having a positive inhalant or ingestant screen, a pet in the household, smoking in the home, ever smoking, mother smoking during the pregnancy, or birth order were not statistically significant.

Discussion

The serum IgEs in this sample were log normally distributed. This has been described both in the general population and in populations of atopic individuals. Population screening for IgE, for reasons discussed in the introduction, is a good index of atopy in the population as well as an index of susceptibility to environmental aero-allergens and pollutants. High levels of atopy in a given population would indicate a large population at risk from atopic disease (asthma, anaphylaxis, allergic rhinitis and eczema) from inhaled or ingested allergens.

The mean raw (53.7 kU/L) and log transformed mean (1.20 kU/L) for serum IgE in the Wabamun sample was comparable to the results obtained for the four other samples studied to date. For example, the mean total serum IgE for Fort McMurray, Lethbridge, Fort Saskatchewan and Grande Prairie were 98.03, 100.3, 46.7, and 58.8 kU/L respectively. Using an arbitrary cutoff point of 100 kU/L as an index of atopy, then in the Wabamun, 11.5% had greater than 100 kU/L compared to 20.6% in Fort McMurray, 21.4% in Lethbridge, and 12.3% in Fort Saskatchewan. Similarly, the percentage of individuals who were positive for one or more specific IgE reactivity's was similar to the previous populations studied (see previous reports).

Of interest in this analysis was that data was available to study relationships between demographic factors, FEV_1 and a history of asthma to its relationship to IgE. Another difference was that the Wabamun sample included two subgroups: children and a group of members of from Paul First Nation. (The results for the children subgroup will be discussed in Appendix A). Paul First Nation members had a significantly higher mean serum IgE than urban/rural participants. This may reflect the higher number of cigarette smokers and males in the Paul First Nation subgroup, the nature of the difference between the two samples cannot be determined from this limited study. There were insignificant numbers of participants overall to do multi-variate analysis to determine if being a member of Paul First Nation membership exerted an independent effect on IgE. This could be investigated in future studies.

Overall, IgE was related to cigarette smoking, a history of asthma and wheezing near trees but not to pets in the household, smoking during pregnancy or birth order. Although there was a relationship between serum IgE and FEV_1 and FVC, this was not significant for the sample as a whole but was marginally significant for the urban/rural participants. The Paul First Nation members had "super-normal" lung function, confirming that standards used for normalizing lung function for aboriginal populations may not always be appropriate.

10.2 Autoantibodies

Background

Autoantibodies are produced by the immune system but unlike normal antibodies which are intended to protect the body; autoantibodies act against healthy cells and tissues and can cause disease. Found in blood samples, autoantibodies are used to aid in the diagnosis and management of many autoimmune diseases such as systemic lupus erythematosus (SLE), Sjögren's syndrome (SjS), systemic sclerosis (SSc), rheumatoid arthritis (RA), vasculitis, and autoimmune liver diseases such as primary biliary cirrhosis (PBC). They can occur in the absence of disease, but usually at low concentrations or titers.[148,149] A study in 2003 showed that the presence of antinuclear antibody (ANA) appears to increase the risk of developing SLE by a factor 40 within a 10 year time frame.[150]

For the past two decades, evidence has been growing that environmental agents and xenobiotics can influence the development and course of autoimmune diseases.[151] Most studies were conducted on cells, rather than organisms, and animals, rather than humans, to investigate the underlying mechanisms of some environmental agents to induce autoimmune disorders.[152,153] A few epidemiological studies in humans have examined the relationship between selected autoimmune disorders and occupational factors such as exposure to pesticides, silica, solvents and mercury in workplaces.[154,155,156,157] The clearest association between exposure to xenobiotics and autoimmune disease is in drug-induced lupus, where a clear cause and effect relationship has been established.[158] Despite this research, no consistent conclusions have been reached about ambient environmental exposures. Therefore, the role of environmental factors in autoimmune disorders for occupational exposures and exposure in the general population remains unclear.

Results

A total of 165 samples were collected for analysis of ANA and some specific autoantibodies. A weakly positive ANA is defined as a value of greater than 1:80 titer. It should be noted that 1:80 titer is not a cut-off point to distinguish between normal individuals and individuals with autoimmune diseases because some autoantibodies are not detected by the ANA screening test. In addition, the results of other published studies vary and cannot be strictly used as comparative data because different laboratories use different detection kits and equipment, and study different populations with different genetic composition. Hence, the use of an Alberta comparison group for this analysis is the most meaningful comparative data. The percentage of participants with a weakly positive ANA was 34% (56/165) in the Wabamun program. These findings are in contrast to a previous Community Exposure and Health Effects Assessment Program conducted in Fort Saskatchewan where 16% (20/128) had positive ANA results.

In the research literature, about 4% to 13% healthy people have weakly positive ANA at 1:80 titer.[159,160,161] Higher prevalence of a weakly positive ANA was observed in 20% of healthy women or 31% of women over 40 years old.[162] In the Wabamun program, 75% individuals with a weakly positive ANA (42/56) were women, and 64% were over 40 years old. This demographic pattern is therefore an important factor in the higher prevalence of positive ANA in the Wabamun participants.

False positive ANA results can occur in various health conditions: viral infection, liver diseases, type 1 diabetes, silicone implant, pregnancy and multiple sclerosis (MS).[163] In the Wabamun program, 63% of individuals with a weakly positive ANA self-reported health conditions and symptoms including cold/flu, diabetes, and arthritis.[164,165] These health conditions, particularly a high rate of self-reported cold/influenza (45%), could increase the rate of positive ANA in this sample.

Since the ANA test is not generally specific enough to identify disease-related autoantibodies, further tests are often performed to clarify a positive ANA result. The most common disease-specific autoantibodies include U1-RNP, SS-B, SS-A, dsDNA, centromere protein and chromatin. The fifty-six (56) positive results detected in the WACEHEAP participants were further tested for these specific autoantibodies. A summary of the specific autoantibody results are provided in Table 57. It is important to note that these serum samples can have one, more than one or none of these disease-related autoantibodies.

Table 57: Autoantibody Specificities

Autoantigen*	Wabamun & Area N=56
U1-RNP	1
SS-B	2
SS-A	5
dsDNA	0
Centromere protein	3
Chromatin	7
Nucleolar	19
Mitochondria	9

Antibodies to the above antigens are seen in the conditions such as SLE, mixed connective tissue disease, drug or xenobiotic-induced lupus, SjS, SSc and PBC. The presence of the autoantibodies in isolation **does not** mean that disease is present and does not invariably predict future autoimmune diseases in healthy individuals. All test results must be interpreted in conjunction with clinical data such as medical history and physical examination.

Environmental Agents

To examine the relationship between selected environmental agents and autoantibody responses, the results from the participants' benzene and mercury levels were compared to their ANA results. The means of urinary mercury were 0.54 µg/L for individuals with a weakly positive ANA and 0.56 µg/L for individuals with negative ANA. The means of urinary muconic were 0.12 µg/mL for individuals with a weakly positive ANA and 0.16 µg/mL for individuals with negative ANA. These results indicate that there was no significant difference of measured levels of urinary mercury or the metabolite of benzene in individuals with positive and negative ANA results.

Health Record Analysis

To investigate further into the higher prevalence of weakly positive ANA results, an analysis of health records was conducted retrospectively over a 10-year span for both the program participants and at a community population level. To do this analysis, three case definitions were created for each of the following diseases: SLE, SjS, SSc and seropositive rheumatic disease – connective tissue (CT) disorders. Three cases definitions were needed to identify stringent cases, moderate cases, and less stringent cases and a 10-year case cohort for each disorder by case definition was created. The cases were extracted from three data sources: the fee-for-service (FFS) physician claims, January 1995–December 2004; the ambulatory care (AC) visits (emergency room visits and day procedures), April 1997–March 2005; and the inpatient hospital (HV) separation data, April 1994–March 2005.

A total of 194 individuals participated in the Wabamun and area program and 603 from the previous CEHEAP studies from four other communities: Lethbridge, Fort Saskatchewan, Grande Prairie, and Fort McMurray. The number and proportion of cases were compared between the Wabamun area and each of four CEHEAP communities and between the lab-positive and lab-negative group within the Wabamun area. Over the 10-year period, a total of 7,823 individuals were diagnosed SLE in Alberta. Of these, 3,091 (39.5%) are likely cases, and 1,671 (21.4%) are probably cases of SLE. A total of 12 possible cases occurred in all 797 CEHEAP participants with only two (1.04%) in the Wabamun area. No difference in the proportion of SLE cases was observed between the participants of the Wabamun area and the other four CEHEAP communities, regardless of case definition. Population level analysis failed to find an increased risk for SLE among the permanent residents of the Wabamun area.

Combining all systematic CT disorders yield a much larger number of cases (N=35,627 for possible cases) but similar finding were found as in the analysis for SLE. For SjS and SS disorders, there was insufficient number of cases within all the CEHEAP studies to complete the health record analysis.

Summary

The presence of positive ANA results in isolation is not diagnostic of an autoimmune disease, but may provide clues as to whether a particular autoimmune disorder or a tendency to develop an autoimmune disorder is likely or unlikely to be present. The higher prevalence (34%) in the WACEHEAP participants may in part be explained by the demographics of the sample. In this sample, there were a high proportion of women, individuals over 40 and individuals suffering viral infections such as colds or flus when they provided samples. Further investigation revealed exposure to environmental agents such as mercury and benzene was not significantly different for either positive or negative ANA participants. In addition, a health record analysis of the WACEHEAP area revealed this area does not have significant different levels of autoimmune disease in comparison to other CEHEAP communities.

10.3 Lung Function

Repeated or chronic exposure to any of the air contaminants measured in this program could potentially lead to a reduction in lung function (e.g. decreased oxygen absorption, increased lung infections or decreased ability to expire). As an indicator of general respiratory health, spirometry is often performed as part of basic medical screening and is used in epidemiological studies addressing public health concerns. Participants in WACEHEAP completed this test at the beginning of the exposure-monitoring period as well as an interviewer-administered respiratory health survey.

Spirometry Test Results

The project co-ordinator attempted to obtain five completed spirometric sessions during the initial interview at the program office. When spirometry is performed, the results are compared with a set of normal or predicted values based upon a participant's age, height, and gender.[166] Reference values are calculated using prediction equations derived from previous epidemiologic studies involving healthy, non-smoking adult populations without a history of disease that could compromise their ventilatory function. Reference values come from studies that are conducted using both equipment and methods compatible with present standards.[167]

Two diagnostically important spirometric test measurements are forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). Specifically, FVC refers to the maximal amount of air that can be forcefully exhaled after a full inhalation. FEV_1 is the volume of air exhaled during the first second of the FVC manoeuvre. The normal range for both FVC and FEV_1 is 80-120% of predicted values.

The average baseline FVC and FEV_1 values were determined by applying the prediction equations of Crapo et al. (1982).[168] Table 58 provides a summary of the findings which indicate the lung function of the participants was within normal range.

Table 58: Summary of Spirometry Data

Lung Function Measurement	Percent of Predicted Value (%)	Standard Deviation
FVC	98.3	14.9
FEV_1	97.1	16.3

Note: These average values reflect normal lung function.

Respiratory Health Survey

Participants also completed the standardized, interviewer-administered European Community Respiratory Health Survey Questionnaire.[169] This questionnaire collected information on respiratory symptoms, smoking status, and past history of respiratory conditions and related medication use.

The percent of respondents in each community who responded "Yes" or "No" to specific questions were compared. Results for the 189 Wabamun participants compared to the 134 Fort Saskatchewan participants, 149 Fort McMurray participants, and 33 Lethbridge participants who completed the survey are summarized in Table 59.

Table 59: Differences in the Prevalence of Reported Respiratory Symptoms between Wabamun, Fort Saskatchewan, Fort McMurray and Lethbridge

Respiratory Symptom	Wabamun N (%)	Fort Saskatchewan N (%)	Fort McMurray N (%)	Lethbridge N (%)
Wheeze within the last 12 months	78 (41.3)	34 (25.4)	43 (28.9)	16 (48.5)
Wheeze in the absence of a cold	33 (17.5)	20 (14.9)	27 (18.2)	10 (30.3)
Waking with chest tightness in the last 12 months	43 (22.8)	17 (12.7)	27 (18.1)	8 (24.2)
Shortness of breath				
• while at rest	25 (13.2)	12 (9.0)	21 (14.1)	6 (18.2)
• while hurrying on level ground or walking up a slight hill	57 (30.2)	26 (19.4)	21 (14.1)	3 (11.5)
Woken by shortness of breath	28 (14.8)	11 (8.2)	10 (6.7)	5 (15.2)
Cough in the morning during winter	45 (23.8)	17 (12.7)	19 (12.8)	2 (6.3)
Phlegm in the morning during winter	40 (21.2)	19 (14.2)	25 (16.8)	6 (18.2)
Ever seen by a doctor for a breathing problem	67 (35.4)	56 (41.8)	41 (27.5)	13 (39.4)
Ever diagnosed by a physician as having asthma	26 (13.8)	24 (17.9)	20 (13.4)	10 (30.3)
Nasal allergies (e.g., hay fever)	54 (28.6)	51 (38.1)	59 (39.6)	15 (45.5)
Eczema/skin allergies	69 (36.5)	43 (32.1)	48 (32.2)	11 (33.3)
Parental asthma/allergy history				
• Mother:				
○ Asthma	10 (5.3)	12 (9.0)	12 (8.3)	0 (0.0)
○ Skin allergies	39 (20.6)	23 (17.2)	30 (21.1)	8 (24.2)
• Father:				
○ Asthma	10 (5.3)	8 (6.0)	7 (4.9)	0 (0.0)
○ Skin allergies	21 (11.1)	17 (12.7)	29 (20.9)	3 (9.4)
Serious respiratory infection before the age of 5	27 (14.3)	12 (9.0)	19 (13.3)	7 (21.2)
Hospitalized over night for breathing problem	15 (7.9)	15 (11.2)	9 (6.0)	2 (6.1)
Total Number of Participants	189	134	149	33

In general, the prevalence of each respiratory symptom reported by WACEHEAP participants compared to three other CEHEAP communities were similar. The two exceptions were "shortness of breathe – while hurrying on level ground/walking up slight hill" and "cough in the morning". Despite a higher number of participants reporting these symptoms, there was not a reflective increase in the number of participants who have ever seen a doctor for a breathing problem or being diagnosed with asthma were comparative to other communities. It should be noted that these are self-reported symptoms and there is a higher percentage of smokers in this sample population versus the other communities surveyed.

10.4 Neurocognitive Functioning

Neuropsychological assessment was conducted to provide a non-invasive means of evaluating associations between exposure and effects to neurocognitive function. Participants completed the Neurobehavioral Evaluation System 2 (NES2), Neuropsychological Impairment Scale (NIS), the Verbal Digit Span section of the Wechsler Memory Scale – Revised (WMS-R), and the Weekly Stress Inventory (WSI). Comparisons were made between control groups of previous studies that have employed versions of the NES to that of the current program.

Neurobehavioral Evaluation System (NES2)

The NES2 is a computerized program that assesses a number of basic neurological and cognitive parameters, including finger tapping, continuous performance, hand-eye co-ordination, associate learning, simple reaction time, symbol-digit, pattern comparison, pattern memory, serial digit learning, switching attention, color-word, and delayed associate recognition.

In order to determine whether the scores obtained from the sample population were any different than other unexposed populations, the sample population was compared to control populations obtained for a variety of other studies. Demographic data along with the description of the measures and control groups for each study is shown in Table 60. It should be noted that not every control group used for comparison administered the same set of activities to their subjects as the current sample; thus, different reference groups are used for different activities.

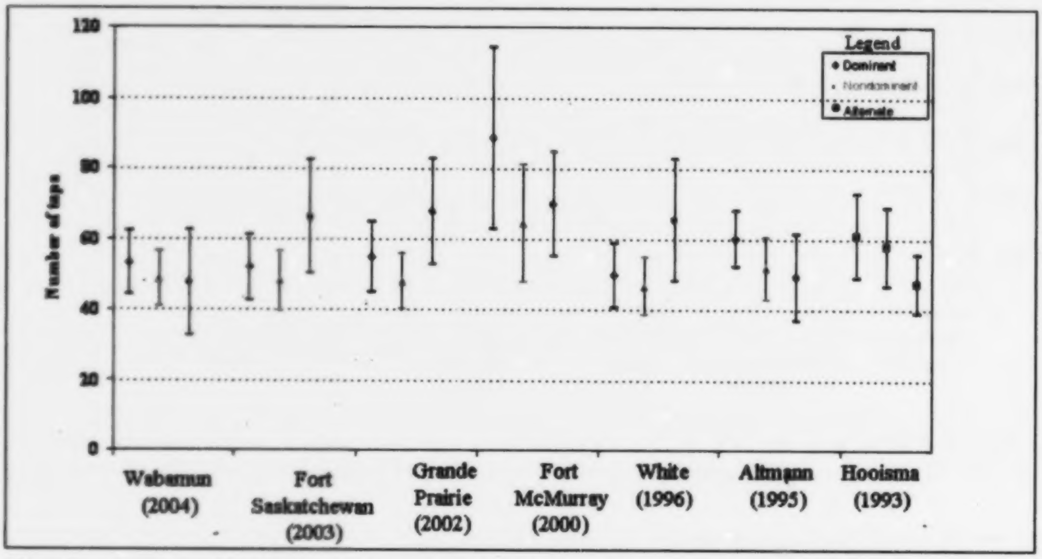
Table 60: Comparison between Study Sample and Other Study Populations

Study/ Author	Study Objectives	Source of Controls	N	Age Mean (SD)	Gender (% Male)	N	Education Mean (SD)
Wabamun	Assess the impact of airborne contaminants on the health of the population	Other Alberta Communities (Ft. Saskatchewan, Grande Prairie	190	45.67 (13.38)	61 (32.1%)	190	16.16 (13.96)
Fort Saskatchewan	Assess the impact of airborne contaminants on the health of the population	Other Alberta communities (i.e., Grande Prairie and Ft. McMurray)	137	47.34 (11.48)	35 (25.4%)	137	13.52 (3.24)
Grande Prairie (2002)[170]	Assess the impact of airborne contaminants on the health of the population	Other Alberta communities (i.e., Fort Saskatchewan and Ft. McMurray)	135	43.27 (11.32)	56 (40.0%)	135	14.02 (3.86)
Fort McMurray[171]	Fort McMurray community exposure to oil sands industry	Community of Lethbridge	300	39.96 (10.05)	135 (45%)	274	14.53 (2.19)
Lethbridge (2000)[172]			33	43.67 (14.14)	15 (45%)	29	14.90 (2.18)
Chuang et al (2005)[173]	Neurobehavioral performance of lead workers	Taiwan – referent group vs. lead workers	96	39.6 (8.5)	19 (100%)	19	9.5 (3.2)

Study/ Author	Study Objectives	Source of Controls	N	Age Mean (SD)	Gender (% Male)	N	Education Mean (SD)
Kilburn et al. (1998)[174]	Population-based prediction equations for neurobehavioral tests	Randomly, from different areas of the United States	264	44.2 (19.7)	121 (46%)	264	12.8 (2.2)
Colvin et al. (1993)[175]	Neurobehavioral effects of chronic solvent exposure on workers in a paint manufacturing plant	Unexposed internal group	24	43.52 (10.04)	24 (100%)	24	6.43 (3.87)
Tsai et al. (1997)[176]	Neurobehavioral effects of exposure to low-level organic solvents among Taiwanese workers in paint factories	Unexposed internal group	47	37.9 (14.8)	38 (81%)	47	10.46 (2.54)
Laire et al. (1997)[177]	Assessment of nocturnal oxygen desaturation in long-term solvent-exposed workers	Army personnel	21	38.1 (11)	20 (95%)	21	11 (2)
Tsai et al. (1996)[178]	Neurobehavioral effects of occupational exposure to low-level styrene	Unexposed internal group	45	35.9 (9.6)	31 (69%)	45	10.6 (2.2)
White et al. (1996)[179]	Validation of NES2 in patients with neurological disorders	Spouses, friends, and family of patients	67	56.5 (12.2)	28 (42.4%)	67	45.5 (2.5)
Muijser et al. (1996)[180]	Behavioral effects of exposure to organic solvents in carpet layers	Cement floor layers	71	37.6 (9.6)	71 (100%)		
Broadwell et al. (1995)[181]	Clinical and neurobehavioral assessment of solvent-exposed microelectronic workers	Unexposed internal group	32	47.6 (9.0)	15 (47%)	32	13.9 (2.2)
Altmann et al. (1995)[182]	Outcome of chronic low-level tetrachloro-ethene exposure of dry cleaning shops	Unexposed personnel of Public Health Office and Medical Institute	23	37.2 (10.1)	9 (39%)		
Hooisma et al. (1993)[183]	Behavioral effects of exposure to organic solvents in Dutch painters	Carpenters and brick-layers	53	36.9 (3.2)	53 (100%)	53	9.4 (1.6)

The following graphs (Figures 90 to 102) compare the performance of the Wabamun cohort to other CEHEAP findings. Overall, there were no significant differences between the current program's participants and the other controls.

Figure 90: NES2 Finger Tapping Test (with 95% Confidence Intervals)



Note: Dominant, nondominant, and alternate refer to the hand that was used during that trial.

Figure 91: NES2 Associate Learning Test (with 95% Confidence Intervals)

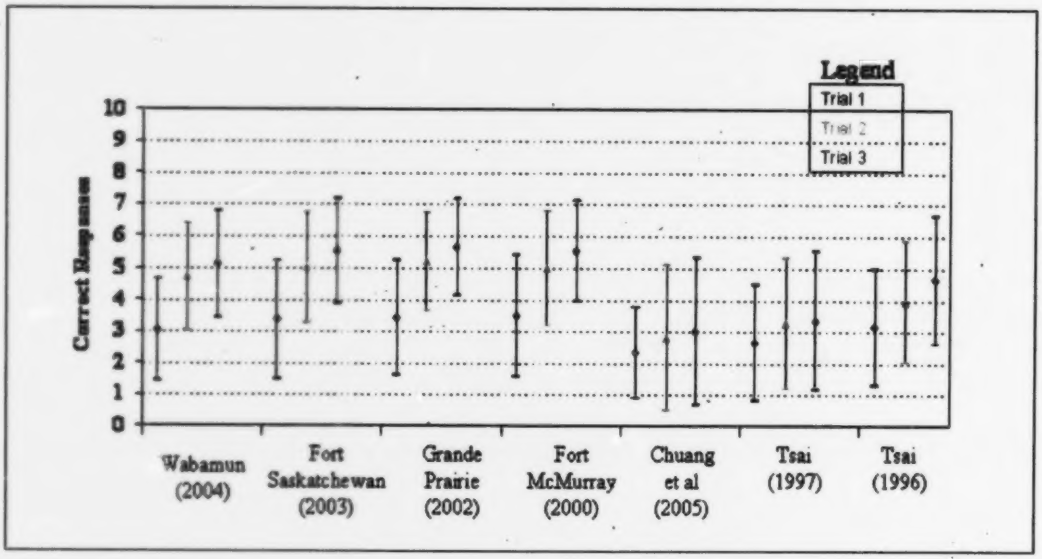
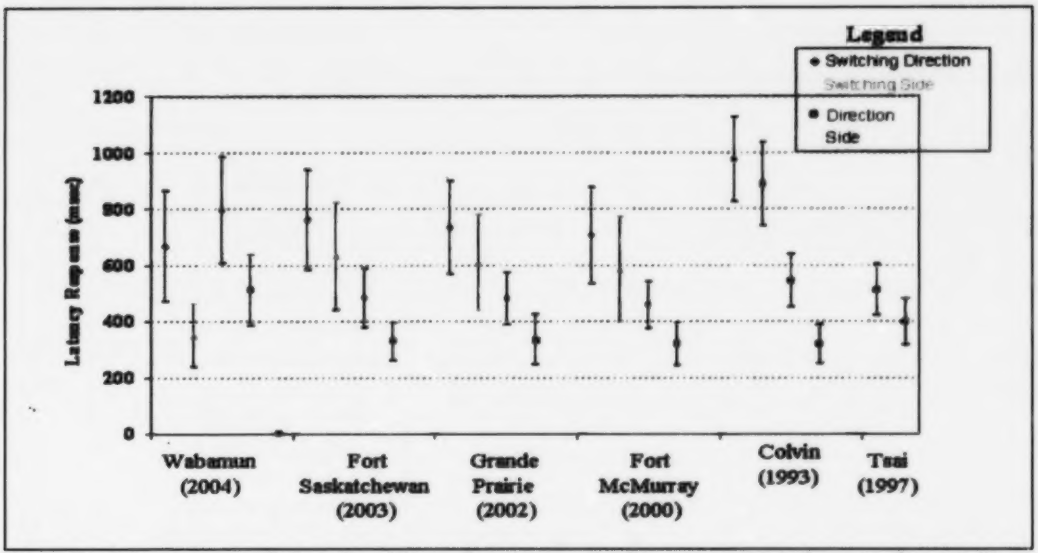
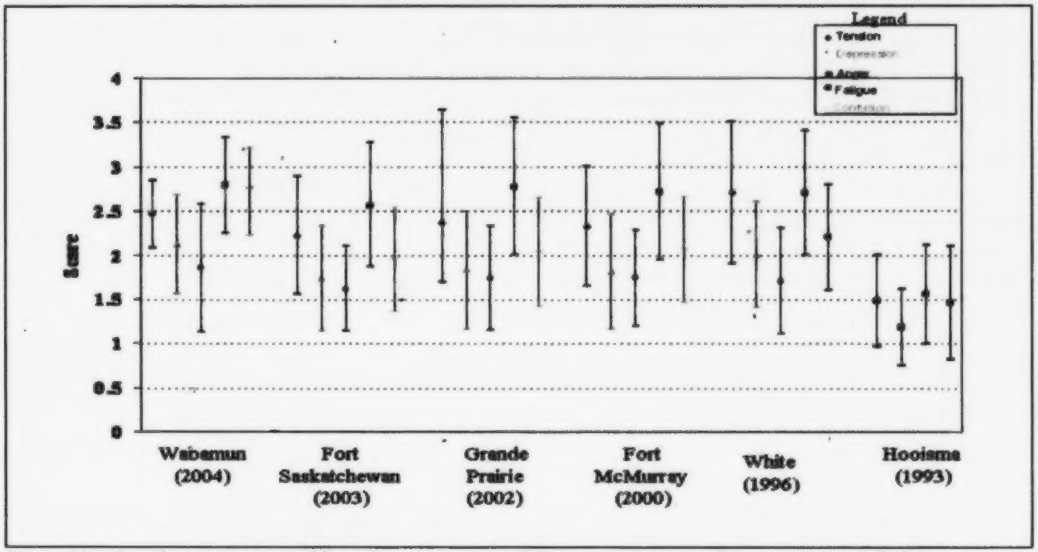


Figure 92: NES2 Switching Attention Test (with 95% Confidence Intervals)



Note: Participants responded to the side or direction a stimulus was presented on; in the switching trials the participant would be cued prior to the presentation of the stimulus to respond to either the side or the direction.

Figure 93: NES2 Mood Scales (with 95% Confidence Intervals)



Note: Mood scales were created based on grouping of the separate items that were responded to.

Figure 94: NES2 Continuous Performance Test (with 95% Confidence Intervals

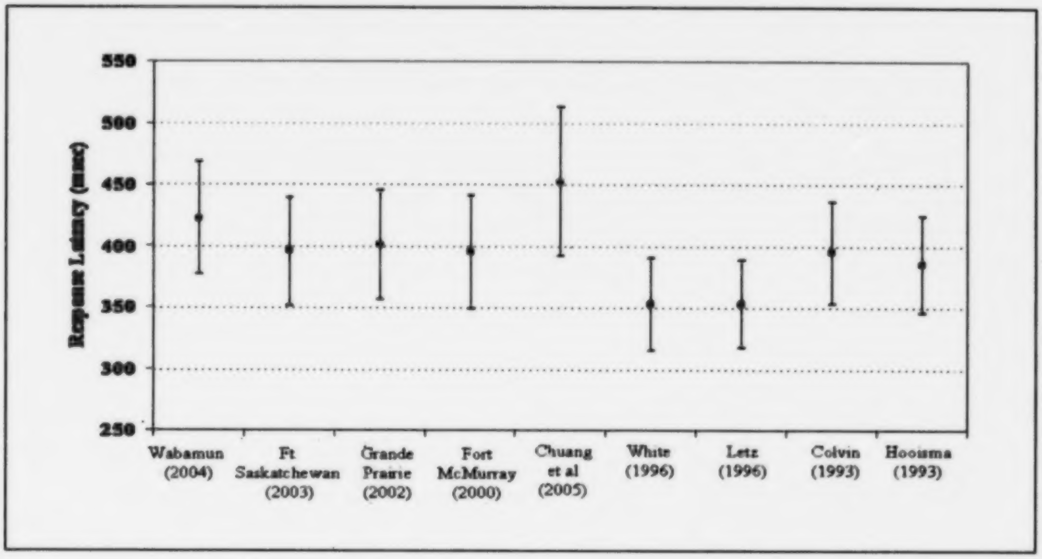


Figure 95: NES2 Simple Reaction Time Test (with 95% Confidence Intervals)

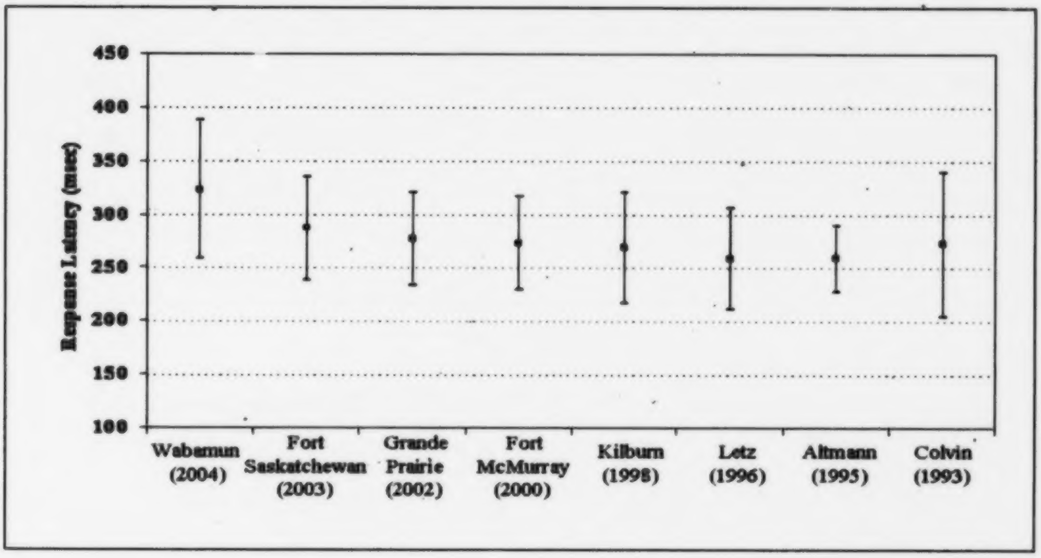


Figure 96: NES2 Symbol-Digit Test (with 95% Confidence Intervals)

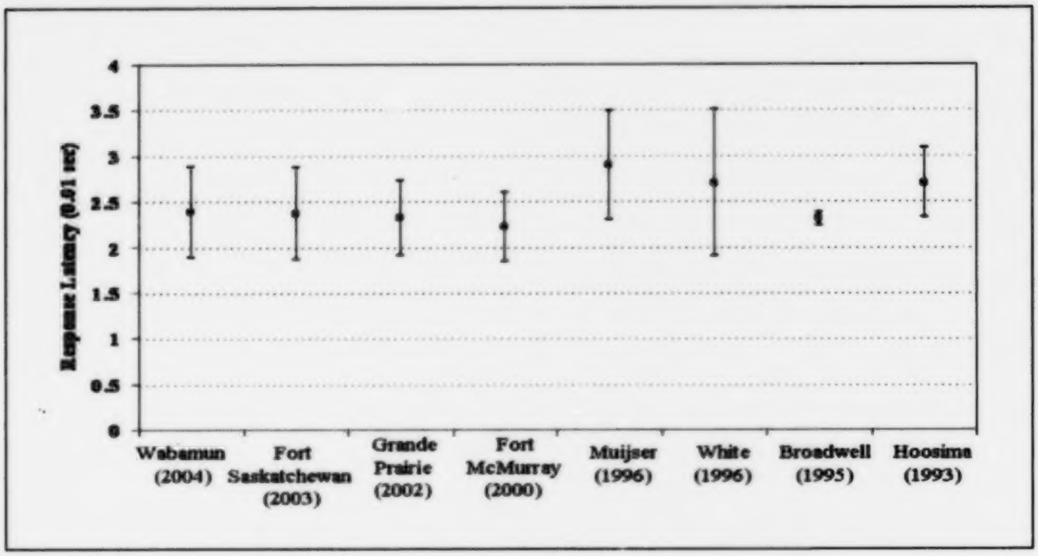


Figure 97: NES2 Pattern Comparison Test (with 95% Confidence Intervals)

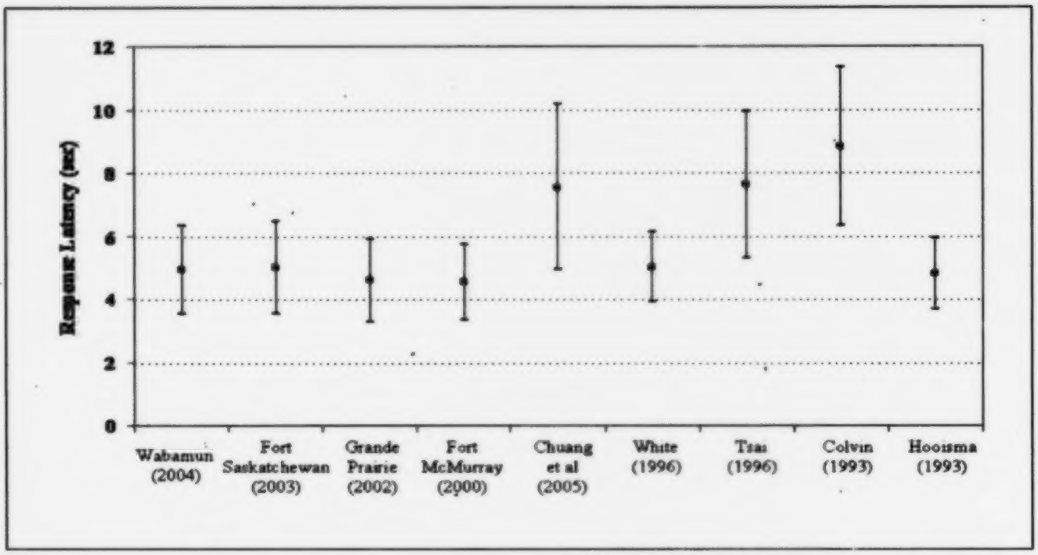


Figure 98: NES2 Pattern Memory Test (with 95% Confidence Intervals)

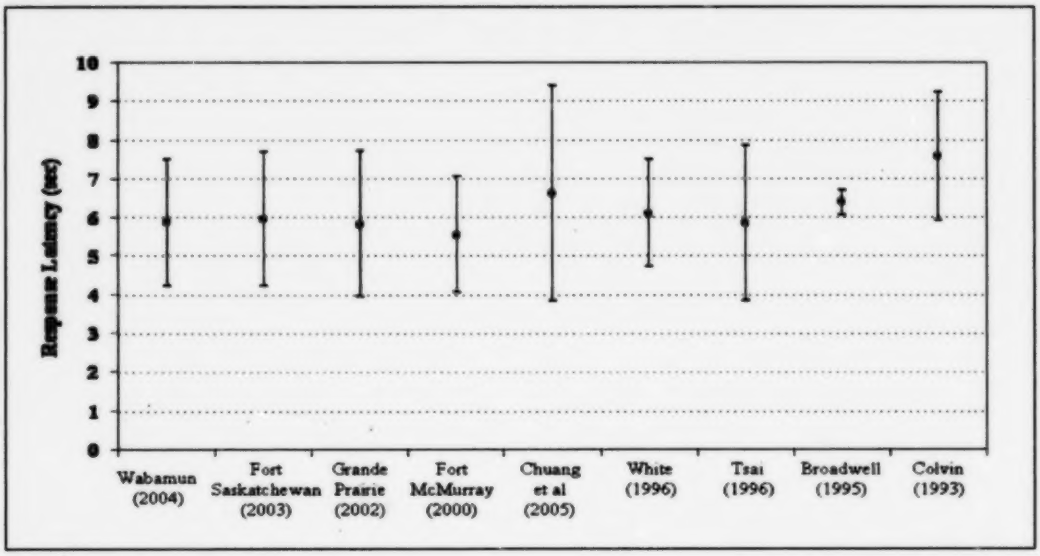


Figure 99: NES2 Serial Digit Learning Test (with 95% Confidence Intervals)

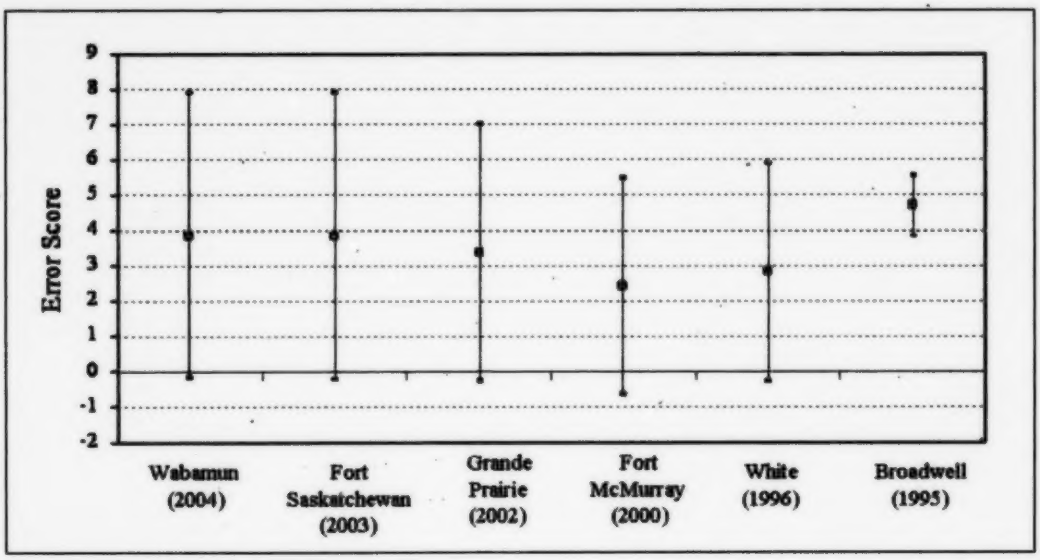


Figure 100: NES2 Colour-Word Test (with 95% Confidence Intervals)

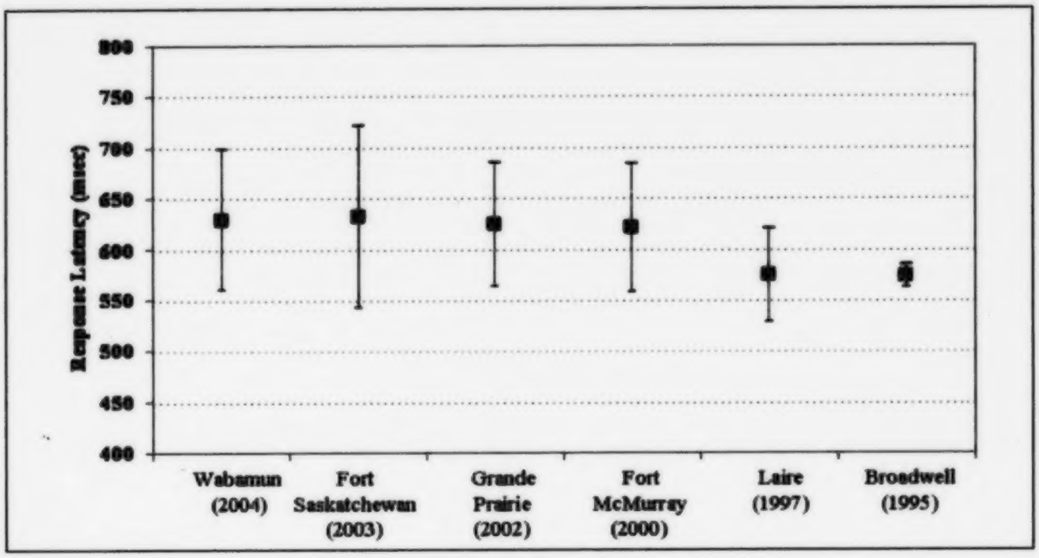


Figure 101: NES2 Vocabulary Test (with 95% Confidence Intervals)

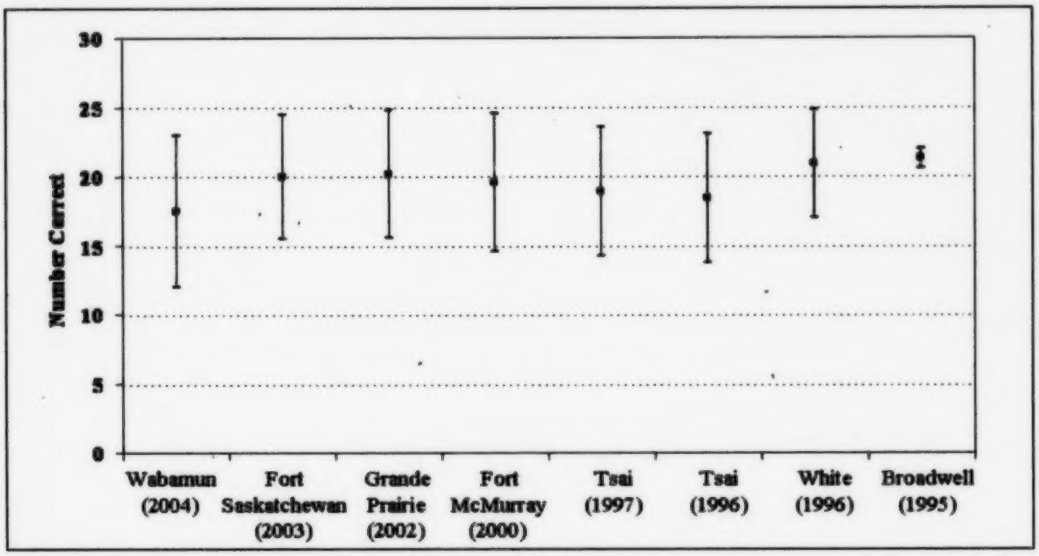
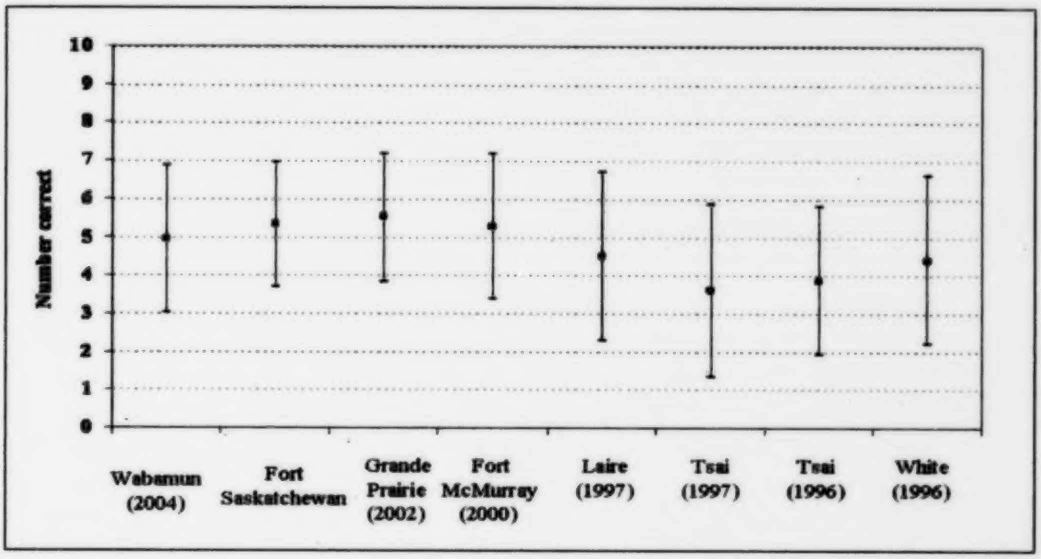


Figure 102: NES2 Delayed Associate Recognition Test (with 95% Confidence Intervals)



Symptoms Questionnaire

A symptom questionnaire was also included in the NES2 program to collect information on symptoms that are often associated with exposure to neurotoxic agents. The questionnaire requires participants to indicate how often they experienced each of the symptoms in the past month. The results of this questionnaire are displayed in the following table (Table 61). The highest reported symptoms for the Wabamun participants was feeling tired (25.4%), lack of sexual drive (18.4%) and difficulty falling asleep (16.2%).

Table 61: Frequency of Experiencing Symptoms (NES2)

Symptoms	Wabamun (N=185, %)			
	Not at all	**A little**	**Fair**	**A lot**
Feeling tired	6.5	40.5	27.6	25.4
Difficulty concentrating	28.1	48.6	16.2	7.0
Difficulty remembering things	8.1	61.6	17.8	12.4
Seizures	97.8	1.6	0.5	0.0
Headaches	41.6	44.3	9.2	4.9
Difficulty falling asleep	38.9	36.2	8.6	16.2
Lack of sexual drive	40.0	29.2	12.4	18.4
Tingling in my fingers or toes	65.9	25.4	2.7	5.9
Loss of appetite	69.7	21.6	7.0	1.6
Diarrhea	74.6	23.2	1.1	1.1
Dry mouth	54.6	32.4	7.0	5.9
Feeling depressed for no reason	55.7	31.4	9.7	3.2
Confusion	58.9	30.8	8.1	2.2
Having to make notes to remember	22.7	42.7	21.1	13.5
Hallucinations	97.8	1.6	0.5	0.0
Heart palpitations	78.9	17.3	2.7	1.1
Lack of co-ordination	69.7	27.6	2.7	0.0
Sleeping more than usual	68.6	19.5	7.6	4.3
Perspiring for no reason	75.1	18.4	2.2	4.3
Skin dryness	53.0	31.9	9.7	5.4
Unexplained weight loss	90.8	7.6	0.5	1.1
Indigestion	57.3	30.3	7.6	4.9
Excessive salivation	84.3	11.4	2.2	2.2
Feeling irritable	35.1	49.2	8.1	7.6
Feeling light-headed or "high"	69.2	22.7	4.9	3.2
Lack of muscle strength	54.3	29.9	9.8	6.0
Tightness in my chest	79.3	16.8	2.7	1.1
Feeling excitable	45.1	41.8	8.7	4.3
Nausea	79.9	16.3	2.2	1.6
Inflamed gums	88.0	9.2	1.6	1.1
Feeling anxious	42.4	44.6	7.6	5.4
Tremor in my fingers	84.8	12.0	1.6	1.6
Loose teeth	91.3	7.6	0.5	0.5
Trembling eyelids, lips or tongue	84.8	12.5	1.6	1.1
Difficulty buttoning clothes	91.8	7.6	0.5	0.0

The items of the symptom questionnaire can be further combined to form seven scales, which are displayed in Table 62. The values reflect the average responses, based on the 4-point scale, of all the symptoms corresponding to their respective categories. These composite scales measure lassitude (weariness), neurasthenia (experience of physical symptoms such as tiredness or exhaustion with no physical justification), memory, confusion, co-ordination, neurological impairment ("neurologic"), and physical health ("physical"). The memory score, which has the highest mean in the program results, reflects the high percentage of "a little" symptoms reported by the participants in Table 62. Similarly, for the neurasthenia, co-ordination, neurological and physical scales, the mean reflects the high percentage of participants who indicated they were "not at all" experiencing these symptoms. Overall, the Wabamun and area program shows no significant differences to previous CEHEAP studies.

Table 62: Symptom Composite Scales (NES2)

Scale	Wabamun Mean (SD)	Fort Saskatchewan Mean (SD)	Grande Prairie Mean (SD)	Fort McMurray Mean (SD)	Lethbridge Mean (SD)
Lassitude	2.20 (0.74)	2.02 (0.66)	2.06 (0.62)	1.99 (0.63)	1.98 (0.57)
Neurasthenia	1.57 (0.42)	1.47 (0.38)	1.54 (0.40)	1.53 (0.40)	1.55 (0.35)
Memory	2.30 (0.76)	2.06 (0.71)	2.06 (0.66)	2.04 (0.69)	2.14 (0.7)
Confusion	1.72 (0.63)	1.54 (0.50)	1.5 (0.46)	1.53 (0.49)	1.53 (0.47)
Co-ordination	1.21 (0.33)	1.19 (0.40)	1.17 (0.38)	1.15 (0.35)	1.21 (0.28)
Neurologic	1.28 (0.31)	1.24 (0.30)	1.22 (0.28)	1.20 (0.22)	1.19 (0.18)
Physical	1.39 (0.32)	1.29 (0.26)	1.33 (0.25)	1.28 (0.24)	1.35 (0.23)
Symptom Mean Intensity	1.54 (0.33)	1.42 (0.29)	1.47 (0.38)	1.41 (0.26)	1.45 (0.22)

Verbal Digit Span (VDS)

The Verbal Digit Span is a section of the Wechsler Memory Scale – Revised (WMS-R)[184] and was administered to each participant as an assessment of auditory processing. The WMS-R version of the Verbal Digit Span is composed of two parts, the Digits Forward and the Digits Backward, which are administered separately. During administration of both sections of the test, the participants are required to repeat increasingly long strings of numbers, either forward or backward, which provide a measurement of the participants' long-term memory.

The following table (Table 63) shows the Verbal Digit Span results for both Digits Forward and Digits Backward. The results of the Wabamun program were comparable to the results of other researchers, including the previous Health Effects and Assessment Programs within Fort Saskatchewan, Grande Prairie[185] and Fort McMurray.[186] In a study conducted by Amitai et al. (1988), control group participants were young (average age=22.2 years), healthy university students.[187] Fastenau (1996) used a comparable group of healthy adults with a mean age of 43.5 years.[188]

Table 63: Verbal Digit Span Results

	N	Digits Forward	Digits Backward
Wabamun and Area	193	7.91 (1.76)	6.75 (2.26)
Fort Saskatchewan	138	8.23 (1.71)	6.20 (2.02)
Grande Prairie (2002)	140	8.34 (1.87)	6.64 (2.21)
Fort McMurray (2000)	334	8.46 (1.94)	6.66 (2.18)
Amitai et al. (1998)	47	8.98 (1.80)	7.83 (2.00)
Fastenau et al. (1996)	47	7.50 (2.10)	NA

11.0 Measures of Health

Several standardized questionnaires were included to obtain measures of the participant's perceived health, as well as measures of mental and psychosocial health. The data collected using the three questionnaires are discussed in the following sections.

11.1 Occupational Health Questionnaire

A standard occupational health questionnaire was used to measure symptoms typically associated with the work environment. The Ontario Ministry of the Environment originally adopted it for the Windsor Winter 1992 Personal Exposure Pilot (PEP) Study. The questionnaire uses a standard list of symptoms, which are characteristically associated with indoor air quality, and requires the respondent to specify the environmental location where the physical symptom is felt. Respondents were allowed to specify multiple locations.

Table 64 identifies the percentage of respondents (N=171) from the Wabamun sample who reported experiencing the specified symptoms in the past year, which are then divided into the specified locations. The symptoms reported most frequently overall were back pain, cold and flu, aching joints and headache. Participants reported experiencing physical fatigue, dry skin, colds and flu, back pain and aching joints as occurring most frequently at home while the most common symptoms at work were strained eyes or focusing difficulties, mental fatigue and throat irritation. Strained eyes and nose and throat irritation occurred most frequently while commuting.

Table 64: Frequency of Experiencing Self – Reported Symptoms

Symptom	None	Home	Work	Commuting	Combination
Eye irritation	52.6	20.5	4.7	1.8	20.5
Nose irritation	57.9	18.7	4.7	2.3	16.4
Throat irritation	46.2	26.3	6.4	2.3	18.7
Dry mucous membranes	67.3	19.9	2.9	1.2	8.8
Dry skin	44.4	34.5	2.9	0.6	17.5
Erythema	86.0	8.2	2.3	0.0	3.5
Mental fatigue	53.2	24.0	7.6	0.0	15.2
Physical fatigue	40.4	36.3	4.7	0.0	18.7
Headaches	50.3	24.6	1.8	0.6	22.8
Unspecified airway infections	89.5	6.4	0.6	0.0	3.5
Scratchy throats or coughs	47.4	26.9	4.1	0.0	21.6
Colds and flu	38.6	33.3	1.8	0.6	25.7
Nausea	66.1	22.2	1.8	1.2	8.8
Dizziness	66.7	19.3	2.9	0.6	10.5
Dry, itching or tearing eyes	56.1	21.6	3.5	0.6	18.1
Strained eyes or focusing difficulties	58.5	18.7	63.5	2.9	16.4
Chest tightness	74.3	17.5	2.3	0.0	5.8
Unspecified hyper-sensitivity	90.1	5.8	0.0	0.0	4.1
Feeling heavy headed	76.6	12.3	1.2	1.2	8.8

Symptom	None	Home	Work	Commuting	Combination
Difficulty concentrating	64.3	17.5	3.5	0.0	14.6
Dry facial skin	66.7	19.9	2.9	0.0	10.5
Aching joints	40.9	33.3	1.8	0.0	24.0
Muscle twitching	68.4	20.5	2.3	0.0	8.8
Back pain	37.4	33.3	1.8	0.6	26.9

11.2 General Health Questionnaire (GHQ)

The General Health Questionnaire (GHQ) is a self-administered screening questionnaire designed to detect current, diagnosable psychiatric disorders.[189] The tool does not identify severe illness, but can identify individuals who feel they are unable to carry out their normal daily functions, focusing on changes in normal functioning rather than lifelong traits. Respondents who report 12 or more complaints are considered to have a psychosomatic disorder.[190]

The mean sum of reported symptoms was 4.1. Over 85% of the respondents scored lower than 12 (refer to Table 65); 9.9% scored between 12 and 24; and just over 3% scored over 25. Contrary to typical findings with this measure, female respondents were somewhat less likely to report experiencing complaints or difficulties than the male respondents.

Table 65: GHQ Score - Percentage of Respondents by Gender

Score	Percentage (%)		
	Males	Females	Total
0 - 11	82.5	88.3	86.8
12 - 24	12.5	9.0	9.9
25 +	5.0	2.7	3.3

11.3 Previous Diagnoses

Program participants were asked to indicate which of a series of chronic diseases they have had diagnosed by a physician. Table 66 shows the percentage of the sample population who have been diagnosed with each specified chronic condition. Statistical analysis indicates that the four communities displayed in Table 66 cannot be distinguished by differing rates of chronic disorders among the participants.

Back problems (27.9%), other allergies excluding food (21.5%) and arthritis (20.9%) were diagnosed most frequently in the Wabamun sample. The percentage of respondents indicating they had been diagnosed with asthma (13.4%) was less than in previous findings whereas the percentage of individuals experiencing bronchitis/emphysema was similar to other communities. More respondents in this sample indicated being diagnosed with diabetes (9.3%) or urinary incontinence (7.6%) than in previous surveys. However, the rates of food allergies, sinusitis, head injury and experiencing migraines were lower. None of the respondents had been diagnosed with Alzheimer's disease or dementia, while low rates were seen for cancer, cataracts, heart disease and effects of stroke. Almost twenty-three percent (22.7%) of the Wabamun respondents indicated they had none of these diagnosed conditions.

Table 66: Percentage with Self-Reported Previously Diagnosed Condition

Diagnosis	Location			
	Wabamun (N = 172)	Fort Saskatchewan (N = 121)	Grande Prairie (N = 121)	Fort McMurray (N = 274)
Food Allergies	9.3	14.0	17.4	12.8
Other Allergies	21.5	28.9	33.9	33.2
Asthma	13.4	19.0	15.7	13.1
Bronchitis/Emphysema	6.4	3.3	6.6	3.6
Sinusitis	7.0	14.9	15.7	12.8
Arthritis	20.9	24.0	19.8	14.2
Back Problems	27.9	28.9	34.7	22.3
Diabetes	9.3	3.3	5.8	2.6
Epilepsy	1.2	0.0	0.8	2.2
High Blood Pressure	16.3	16.5	11.6	9.5
Heart Disease	2.9	3.3	2.5	1.1
Effects of Stroke	0.6	2.5	0.0	0.7
Cancer	5.8	5.0	5.0	1.8
Alcoholism	1.2	1.7	1.7	1.1
Urinary Incontinence	7.6	4.1	5.0	1.8
Kidney Failure/Disease	2.3	1.7	0.8	0.7
Acne requiring medication	3.5	10.7	7.4	5.5
Cataracts	2.9	0.8	4.1	0.4
Glaucoma	1.2	0.0	0.8	0.4
Migraine	9.3	9.1	16.5	10.9
Head Injury	2.3	4.1	6.6	5.8
Alzheimer's Disease	0.0	0.0	0.0	0.0
Dementia	0.0	0.0	0.0	0.0
Emotional Illness	8.7	8.3	6.6	4.0
Mental Health Condition	4.7	2.5	7.4	2.9
Nervous System Disease	3.5	4.1	2.5	1.5
None of the Diagnoses	22.7	21.5	13.0	21.5

12.0 Analysis of Health Records

One of the objectives of the Wabamun and Area Community Exposure and Health Effects Assessment Program (WACEHEAP) was to describe the distribution of human health outcomes potentially associated with exposure to airborne contaminants. This section of the report uses a population-based study, with health records as a proxy measure of health outcomes to compare selected morbidity and mortality measures between residents of the Wabamun area and those from other CEHEAP comparative communities available. The other comparative communities include Lethbridge, Fort Saskatchewan and area, Grande Prairie and area, and Fort McMurray. Previous studies did not show significant differences in morbidity and mortality measures between these communities.[191,192,193]

This analysis will address two questions:

1. Is there an increased health risk for residents of the Wabamun and area?

2. Were the health care services obtained by the program participant's representative of the services obtained by the population of the Wabamun and area?

A population cohort from the two groups was created from the Alberta Health Care Insurance Plan (AHCIP) Stakeholder Registry. Records for the members of the cohort were added from January 1, 1995 until either December 31, 2004. Members remained part of the cohort until the individual died or moved out of the area. Records from the Alberta Fee-For-Service (FFS) Claims File, the Alberta Ambulatory Care Classification System (ACCS) and the Alberta In-Patient Hospital Morbidity File were linked to this file for each individual. The resulting database included demographic, socio-economic, residential history information, physician visits, ambulatory care visits, and hospital stays. Since some patients may not be captured in the primary diagnosis, we included all three diagnoses available in FFS claims and first six diagnoses in ambulatory care and inpatient hospital care. Three case definitions were developed for four respiratory disorders according to the nature of disease and their statistical distribution, ranging from stringent cases, to moderate cases, and less stringent cases (Appendix C).

Overall, there were 114,025 people residing in the program boundaries and 310,312 people residing in the CEHEAP comparative communities between January 1995 and December 2004. Of these, 28,882 (25.2%) from the WACEHEAP area and 90,366 (29.2%) from the comparative communities entered into the cohort in 1995 for a complete 10 years of observation. For those with 10 years of observation, 17,111 (59.2%) from the WACEHEAP area and 47,837 (52.9%) from the comparative communities had the same residence postal coded reported between January 1995 through December 2004. An annual postal code-based population from 1984 to 2004 was also generated for comparison between communities over time.

A cohort design was used for morbidity measures, focusing on the period prevalence over 10 years (1995-2004) of measurement. A cross-sectional approach was applied for analysis of overall illness (January to December 2004) and mortality (1984-2004). The 3-year combined mortality was calculated to minimize the potential instability of rates due to small numbers. To control for confounding effects due to differences in the age distribution across communities and time period, the mortality rate and prevalence were adjusted to the age distribution of the 1996 Canadian census population. The standard error and 95% confidence interval (CI) of the age-adjusted rate were calculated.[194] When the 95% CI do not overlap, the differences are statistically significant, though slightly overlapping CIs might also be statistically significant (at a p-value of 0.05). Multivariate logistic regression was used to control for the effect of potential confounding factors from age, sex, First Nations, and socio-economic status in the analysis of the morbidity measures. Since the residence was used as a proxy measure of exposure, the final assessment of the cohort study was limited to permanent residents only. The number of permanent residents is 17,111 individuals from the WACEHEAP area and 47,837 individuals from the comparative communities.

Characteristics of the Population

A comparison of the population living in the WACEHEAP area versus the population living in the comparative communities indicates a number of differences. As described in Table 67, the WACEHEAP program area had slightly more seniors (6.4% vs. 5.8%), fewer First Nations people (2.6% vs. 5.1%), and more individuals of low (13.3% vs. 12.4%) socio-economic status. In addition, a smaller percentage of the population remained in the community for the complete 10-year period compared to the comparative communities. Of those with complete 10-years of observation, 59.2% of the Wabamun area residents and 52.9% of comparative communities residents stayed in the same residence postal code area over the 10-year period.

Table 67: Demographic and Socio-economic Characteristics of Community Populations, 1995-2004

Demographic and Socio-economic Factors	**Category**	**WACEHEAP (N=114,025)**		**CEHEAP Comparative Communities (N=309,592)**		***p*-value**
		N	**%**	**N**	**%**	
Sex	Male	57,786	50.7	157,962	51.0	$p = 0.05$
	Female	56,239	49.3	151,630	49.0	
Age Group	0-14	33,321	29.2	87,523	28.2	$p < 0.001$
	15-64	73,393	64.4	204,645	66.0	
	65+	7,278	6.4	17,891	5.8	
First Nations Status [1]	Yes	2,946	2.6	15,688.	5.1	$p < 0.001$
	No	111,079	97.4	294,614	94.9	
Socio-economic Status (SES) Surrogate Indicator	Lower[2]	3,402	3.0	9,718	3.1	$p < 0.001$
	Low[3]	15,129	13.3	38,498	12.4	
	Average[4]	95,494	83.7	262,086	84.5	
Complete 10-Year Observation[5]	Yes	28,882	25.3	90,366	29.2	$p < 0.001$
	No	85,143	74.7	219,226	70.8	
Mobility Status, 1995-2004	Moved[6]	11,771	40.8	42,529	47.1	$p < 0.001$
	Not Moved[7]	17,111	59.2	47,837	52.9	

[1] *Individuals registered with AHCIP had a treaty status and/or band number at the time of registration and/or updating.*

[2] *Lower: Receiving both social assistance and AHCIP subsidy.*

[3] *Low: receiving AHCIP subsidy only.*

[4] *Average: Non-AHCIP subsidy and non-social assistance recipient.*

[5] *Entered into the population cohort in January 1995 and still registered with AHCIP by December 31, 2004.*

[6] *Changed the residence postal code over a 10-year period of observation.*

[7] *Individuals with a complete 10-year follow-up who had the same residence postal code reported from 1995 through 2004.*

12.1 Morbidity of Respiratory Disorders

Respiratory disorders, particularly asthma, have received significant attention in studies of the potential impact of ambient air quality on human health.[195,196] For example, several studies have reported a positive association between ambient air pollution and hospital admissions for asthma and other respiratory disorders.[197] For the purposes of this evaluation, the analysis focused on measures of morbidity due to asthma, bronchitis, Chronic Obstructive Pulmonary Disease (COPD), and all respiratory disorders combined.

10-Year Period Prevalence of Respiratory Disorders by Age Group, 1995-2004

The 10-year period prevalence of asthma, bronchitis, COPD, and all respiratory disorders was calculated by age group for the permanent residents of the Wabamun and area and CEHEAP comparative communities from 1995 through 2004.

As Table 68 shows, compared to the residents of comparative communities, children 0-14 years of the Wabamun and area have a lower prevalence of asthma, bronchitis, and COPD but a slightly higher prevalence of all respiratory disorders ($p<0.01$). In contrast, for people 15-64 years old no difference was found for asthma ($p>0.05$), but a lower prevalence of bronchitis and COPD and a 2% higher prevalence of all respiratory disorders among the residents of the Wabamun and area ($p<0.05$). For people 65 years and over, the residents of the Wabamun and area have a higher prevalence of asthma ($p=0.002$), but no significant difference in bronchitis, COPD, and all respiratory disorders ($p>0.05$). When all ages are combined, the residents of the Wabamun and area have lower prevalence of bronchitis (13.6% vs. 15.7%) and COPD (15.8% vs. 18.1%) but a higher prevalence of all respiratory disorders (85.0% vs. 83.6%), with no difference for asthma (16.7% vs. 16.4%).

Table 68: 10-Year Period Prevalence of Selected Respiratory Disorders by Age Group among Permanent Residents: Wabamun area vs. Other CEHEAP Communities, 1995 – 2004

Diagnostic Group	Age Group	WACEHEAP		Comparative Group [3]		Group Comparison	
		N[1]	%[2]	N[1]	%[2]	Ratio	p-value[5]
Asthma	0-14	1,086	23.7	3,097	25.8	0.92	0.005
	15-64	1,543	13.6	4,067	13.0	1.05	0.100
	65+	225	18.7	691	15.0	1.24	0.002
	Total	**2,854**	**16.7**	**7,855**	**16.4**	**1.02**	**0.437**
Bronchitis	0-14	475	10.4	1,618	13.5	0.77	< 0.001
	15-64	1,546	13.7	4,837	15.5	0.88	< 0.001
	65+	304	25.3	1,058	23.0	1.10	0.099
	Total	**2,325**	**13.6**	**7,514**	**15.7**	**0.87**	**< 0.001**
COPD	0-14	501	10.9	1,685	14.0	0.78	< 0.001
	15-64	1,791	15.8	5,496	17.6	0.90	< 0.001
	65+	404	33.6	1,465	31.9	1.05	0.254
	Total	**2,696**	**15.8**	**8,647**	**18.1**	**0.87**	**< 0.001**
All Respiratory Disorders	0-14	4,293	93.6	11,074	92.3	1.01	0.004
	15-64	9,265	81.8	25,173	80.6	1.02	< 0.001
	65+	989	82.3	3,742	81.4	1.01	0.502
	Total	**14,547**	**85.0**	**39,992**	**83.6**	**1.02**	**< 0.001**

[1] *The number of individuals with a given condition between January 1995 and December 2004.*

[2] *The number of cases per 100 population between January 1995 and December 2004.*

[3] *Including Fort McMurray, Lethbridge, Grande Prairie, and Fort Saskatchewan communities*

[4] *The rate ratio of Wabamun over the comparative community; the ratio greater than one (1) indicates an increased risk and ratio lower than one (1) a decreased risk.*

[5] *Chi-square test for the difference in rate between the permanent residents of two areas.*

10-Year Period Prevalence of Respiratory Disorders by First Nations Status, 1995-2004

Table 69 presents the 10-year period prevalence of asthma, bronchitis, COPD, and all respiratory disorders for the permanent residents of the WACEHEAP area and CEHEAP comparative communities stratified by First Nations status.

As shown, compared to non-First Nations group, First Nations people have a higher prevalence of asthma, bronchitis, COPD and all respiratory disorders for both the WACEHEAP and comparative communities. There are no difference in prevalence of asthma between the WACEHEAP and comparative communities regardless of First Nations status (p >0.05). Compared to comparative communities, the WACEHEAP area have a lower prevalence of bronchitis and COPD among both First Nations people and non-First Nations residents (p<0.001). In contrast, the prevalence of all respiratory disorders is slightly higher among non-First Nation residents of the WACEHEAP area but not for First Nations residents of this area (p>0.05).

Table 69: 10–Year Period Prevalence of Respiratory Disorders by First Nations Status among Permanent Residents Wabamun area vs. Other CEHEAP Communities, 1995 – 2004

Diagnostic Group	First Nation Status	WACEHEAP (N=17,111)		Comparative Group (N=47,837)[4]		Group Comparison	
	Status[1]	N[2]	%[3]	N[2]	%[3]	Ratio[5]	p-value[6]
Asthma	Yes	67	20.9	323	18.1	1.15	0.246
	No	2,787	16.6	7,533	16.4	1.01	0.467
	Total	**2,854**	**16.7**	**7,856**	**16.4**	**1.02**	**0.437**
Bronchitis	Yes	53	16.5	493	27.7	0.60	< 0.001
	No	2,272	13.5	7,021	15.2	0.89	< 0.001
	Total	**2,325**	**13.6**	**7,515**	**15.7**	**0.86**	**< 0.001**
COPD	Yes	55	17.1	506	28.4	0.60	< 0.001
	No	2,641	15.7	8,141	17.7	0.89	< 0.001
	Total	**2,696**	**15.8**	**8,648**	**18.1**	**0.87**	**< 0.001**
All Respiratory Disorders	Yes	285	88.8	1,564	87.8	1.01	0.623
	No	14,262	84.9	38,428	83.4	1.02	< 0.001
	Total	**14,547**	**85.0**	**39,993**	**83.6**	**1.02**	**< 0.001**

[1] *Individuals registered with AHCIP had a treaty status or band number at the time of registration and/or updating.*

[2] *The number of individuals with a given condition between January 1995 and December 2004.*

[3] *The number of cases per 100 population between January 1995 and December 2004.*

[4] *Including Fort McMurray, Lethbridge, Grande Prairie, and Fort Saskatchewan communities.*

[5] *The rate ratio of Wabamun over the comparative community; the ratio > one (1) indicates an increased risk and ratio < one (1) a decreased risk.*

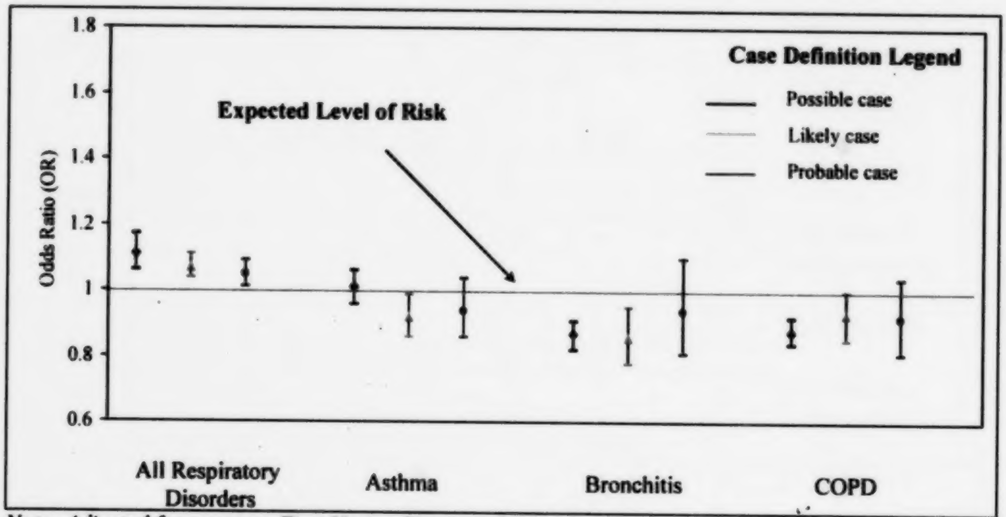
[6] *Chi-square test for the difference in rate between the permanent residents of two areas.*

Comparison of the Risk for Asthma, Bronchitis, COPD, and Respiratory Disorders

Further to the above analysis, this section examines the risk for prevalence of asthma, bronchitis, COPD and all respiratory disorders combined while controlling for the confounding effects of age, sex, First Nations and socio-economic status simultaneously. The 10-year period prevalence of the four conditions was calculated for the permanent residents of the WACEHEAP area and that of comparative communities using three case definitions. The case definition was developed similar to other CEHEAP initiatives but extended the data from physician office visit and hospitalization to physician office visit, hospitalization, and ambulatory care visit. In the development of case definition, effort is made to account for the nature of each condition and its statistical distribution in the Alberta health care system (Appendix C). It is assumed that if the residents of the WACEHEAP area have more exposure than the residents of other CEHEAP communities, the adjusted risk for asthma, bronchitis, and COPD will be higher than 1.

As shown in Figure 103, in 1995-2004 there is no increased risk for asthma, bronchitis, and COPD among the residents of the WACEHEAP area, regardless of case definition. Overall, the adjusted risk for these three conditions tended to be lower among the residents of the Wabamun and area than the CEHEAP comparative communities. Of note, however is the adjusted risk for all respiratory disorders combined among the residents of the WACEHEAP area is higher than the CEHEAP comparative communities for a possible case, a likely case, and probable case ($p<0.01$). The increased risk for all respiratory disorders is not clear though it is not impossible that this increase is due to more common cold and other upper respiratory infections in children and seniors.

Figure 103: Estimated Relative Risk for Prevalence of Selected Respiratory Disorders: WACEHEAP Compared to CEHEAP Comparative Communities, 1995-2004



Note: Adjusted for sex, age, First Nation Status and SES Marker.

The Frequency of Visits for Selected Respiratory Disorders by Community

One of the questions raised is whether residents of the WACEHEAP area visit a physician, emergency room or a hospital more frequently for a given disease. Table 70 shows the mean and median number of days of visits for asthma, bronchitis, COPD, and all respiratory disorders among the permanent residents of the Wabamun and area and the CEHEAP comparative communities during the 10-year period of observation.

As shown, there is no significant difference in the adjusted mean visit for asthma, COPD, and all respiratory disorders combined between the two comparison groups. On average, the residents of the WACEHEAP area visited a physician, emergency room, or a hospital for bronchitis slightly more frequent (3.1 days, SD=4.7) than the residents of the comparative communities (2.7 days, SD=2.9) due to a few extreme cases.

Table 70: Mean and Median Number of Visits for Selected Respiratory Disorders by Community, the 1995 Population Cohort during a 10-Year Observation

Diagnostic Category	Comparison Group	# Persons with Diagnosis[1]	# Mean[2] (Visits)	SD	Median (Visits)	p-value[3]
Asthma	WACEHEAP	2,854	5.9	10.9	2	0.098
	Comparative Communities[4]	7,856	6.5	19.1	2	
Bronchitis	WACEHEAP	2,325	3.1	4.7	1	<0.001
	Comparative Communities[4]	7,514	2.7	2.9	1	
COPD	WACEHEAP	2,696	3.5	5.9	1	0.05
	Comparative Communities[4]	8,647	3.9	8.9	1	
All respiratory Disorders	WACEHEAP	14,547	12.5	12.8	6	0.065
	Comparative Communities[4]	39,992	12.2	15	5	

[1] *The number of individuals with a given diagnosis of respiratory disorders who are registered with AHCIIP from January 1995 through December 2004 and had the same residence postal code reported over the 10-year period.*

[2] *The adjusted average number (least square mean) of visits for a given diagnosis over 10 years (1995-2004) in a regression model. Adjusted for the effects of age, sex, SES markers, First Nations status and data source*

[3] *The p-value of the F test for the statistical inference.*

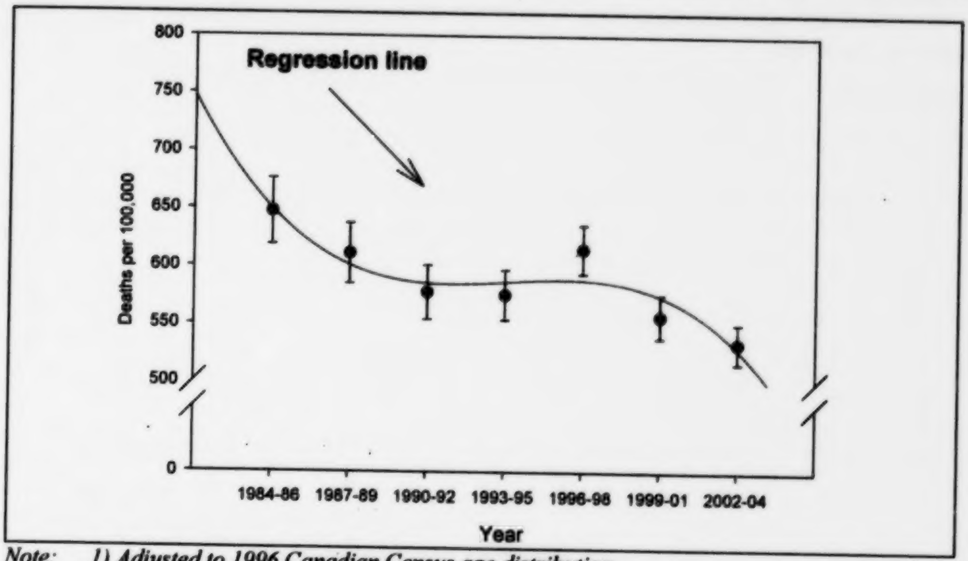
[4] *Including Fort McMurray, Lethbridge, Grande Prairie and area, Fort Saskatchewan and area*

12.2 Mortality of Selected Causes of Death

Mortality rates have frequently been used as an outcome measure in environmental epidemiological studies. Several studies have examined the relationship between the ambient air quality and mortality due to respiratory disorders, cardiovascular disease[198,199,200] or death from any cause.[201,202,203]

Figure 104 shows the 3-year combined age standardized mortality rate from all causes of death for the residents of the WACEHEAP area, 1984-2004. There was no increase in the standardized mortality rate for all causes of death in the WACEHEAP area over a 21-year period (although the mortality rate was lower in 2002-2004 and slightly higher in 1996-1998).

Figure 104: Age- Standardized Mortality Rate of All Causes of Death, WACEHEAP, 1984 – 2004

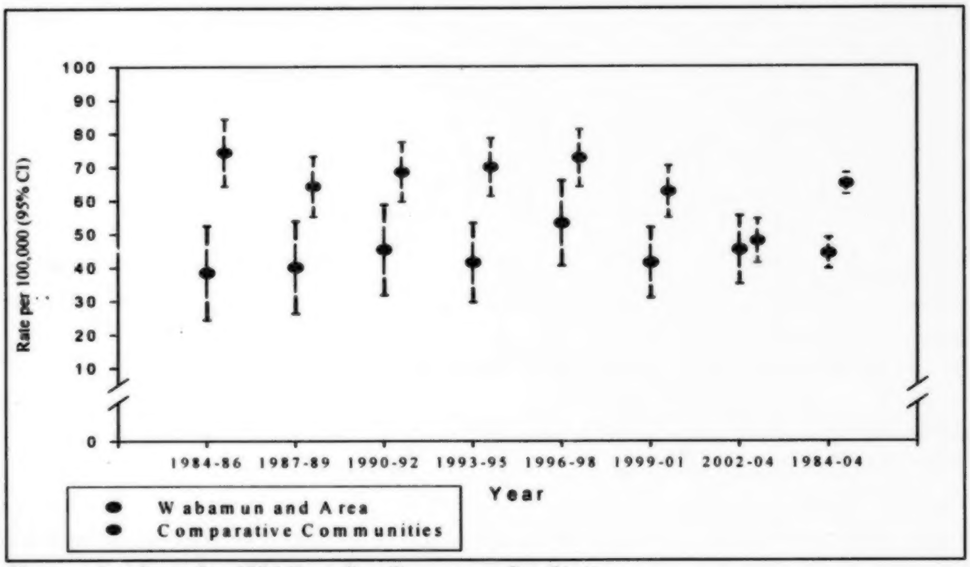


Note: *1) Adjusted to 1996 Canadian Census age distribution.*
2) All causes of death of underlying disease: ICD-9 = 001-999, ICD-10 = A00-Y98

The rate of mortality from respiratory disorders, COPD, and all causes combined between the years 1984 to 2004 were compared for the residents of the WACEHEAP area and the residents of the other four (4) CEHEAP comparative communities. There was no evidence of an increased risk of death for residents of the WACEHEAP area from respiratory disorders, COPD, or all causes of death combined for any of the 3-year period examined during 1984 and 2004 (Figures 105A, 105B, 105C, and 105D).

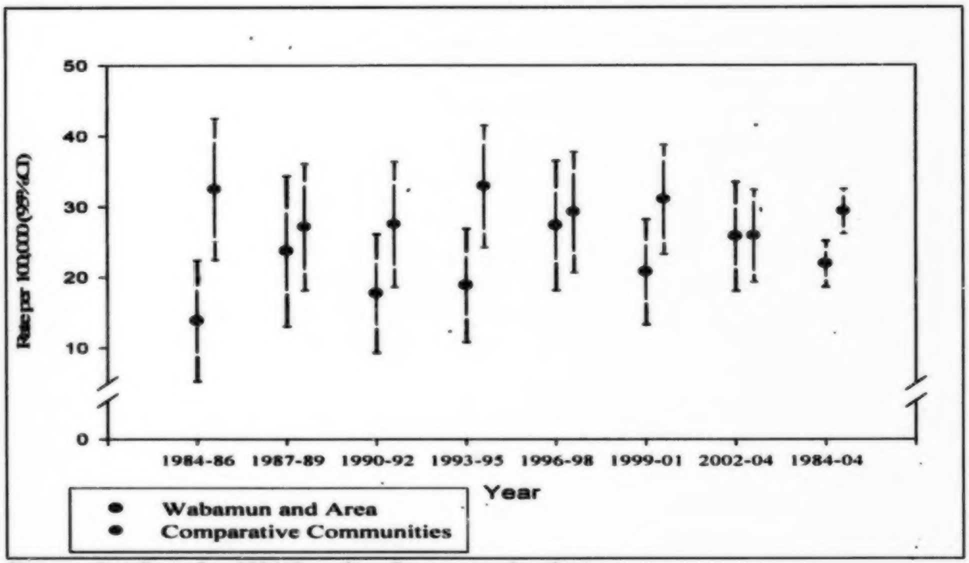
Figure 105: Comparison of Age Standardized Mortality Rates of Selected Causes of Death Between the WACEHEAP and Comparative CEHEAP Communities, 1984-2001 (with 95% Confidence Interval)

A. Respiratory Disorders



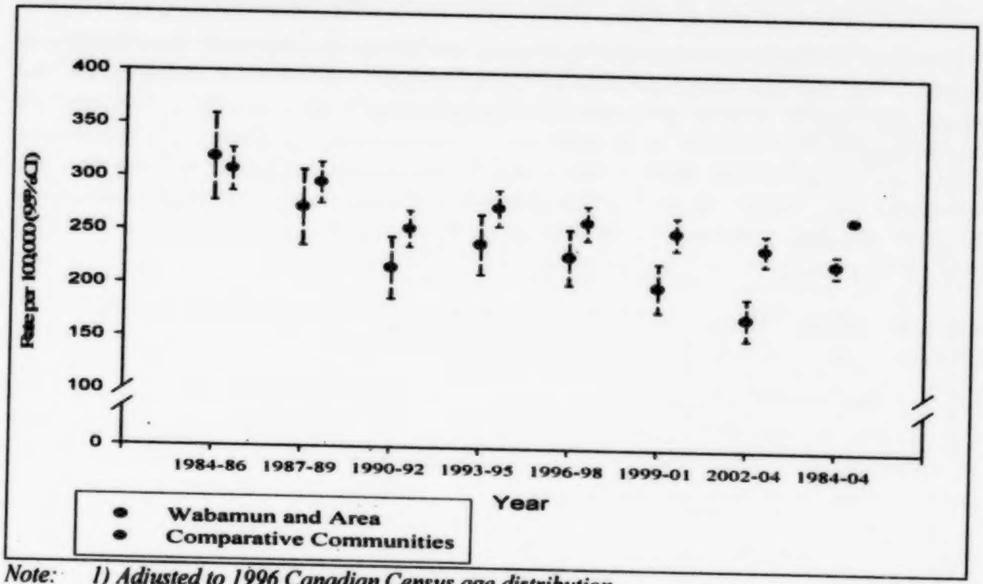
Note: 1) Adjusted to 1996 Canadian Census age distribution.
2) Respiratory Disorders: ICD-9 = 460-519; ICD-10 = J00-J99.

B. COPD



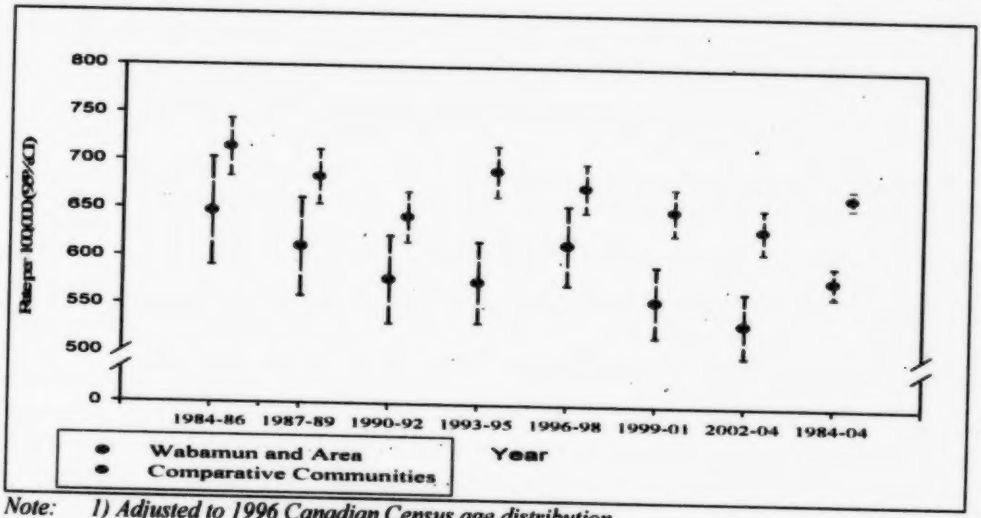
Note: 1) Adjusted to 1996 Canadian Census age distribution.
2) Chronic Obstructive Pulmonary Diseases (COPD): ICD-9=490-492, 494, 496; ICD-10=J40-J44, J47

C. Major Cardiovascular Diseases



Note: *1) Adjusted to 1996 Canadian Census age distribution.*
2) Major cardiovascular disease: ICD-9 = 390-434, 436-448; ICD-10 = I00-I78

D. All Causes of Death



Note: *1) Adjusted to 1996 Canadian Census age distribution.*
2) All causes of death of underlying disease: ICD-9 = 001-999; ICD-10 = A00-Y98

12.3 Comparison of Overall Illness: Participants vs. the General Population

Health records from Fee-For-Service claims between January and December 2004 were used to compare program participants with the general population of the Wabamun and area to determine if the participants accessed health care services differently than the resident population of the community. Of 194 participants, 91.8% (n=178) visited a Fee-For-Service (FFS) health care practitioner between January and December 2004. Overall, this proportion is higher than for the general population of the community (86.3%) (refer to Table 71). However, the average number of visits per year was slightly lower for participants (8.9 visits per year) compared to the resident population of the community (10.1 visits per year) due to fewer visits among younger (18-24 year) and older (65+) participants.

Table 71: Proportion Visiting a Health Care Provider and Average Number of Visits for Any Illness by Age Group, Wabamun and Area, January to December 2004

Age Group	WACEHEAP Participants (n=194)		General Population (n=50,681)	
	Proportion[1] (%)	Mean[2] Visit/Case-Year	Proportion[1] (%)	Mean[2] Visit/Case-Year
18-24	91.7	5.1	81.9	7.0
25-34	94.1	9.3	83.2	8.6
35-44	94.1	7.0	83.3	8.6
45-54	83.3	10.7	85.7	9.7
55-64	93.0	9.6	90.6	11.2
65+	100.0	11.1	95.9	16.1
Total	91.8	8.9	86.3	10.1

[1] *The number of individuals who visited a Fee-For-Service practitioner at least once for any illness per 100 person year under observation.*

[2] *The average number of visits per person with illness of a given age group, January to December, 2004.*

12.4 Summary of Analysis of Health Records

Findings from the analysis of health records suggest the following:

- There is no evidence of either a significantly higher morbidity (period prevalence, frequency of visits) of asthma, bronchitis, and COPD in the Wabamun and area, nor an increased risk of death from all causes, respiratory disorders, COPD, and major cardiovascular diseases in this area.

- There is evidence of an increased prevalence and frequency of visits for all respiratory disorders combined in the Wabamun and area. However, the mean visits of asthma and COPD are lower when compared to other CEHEAP communities. Continued surveillance of respiratory disorders is recommended.

- There is a difference in the Fee-For-Service physician visits for overall illness between the program participants and non-participants. Overall illness refers to any type of illness or access to any type of health care service.

13.0 Exposure Sources

An objective of the Wabamun and Area Community Exposure and Health Effects Assessment Program was to quantify the relative contributions of various exposure sources and pathways to airborne chemicals. This section of the report will discuss sources of exposure drawing on an analysis of wind and ambient air quality data and some of findings of the previous section that addressed exposure pathways. This assessment qualitatively compares the relative contributions of indoor versus outdoor exposure sources and further categorizes the outdoor sources as local (close by sources), regional (industry or other communities in the surrounding area), and background (levels not due to regional or local sources).

The characterization of outdoor sources was accomplished through the analysis of wind and concentration data collected from Genesee, Wagner, and Meadows air monitoring stations located in the program area. The analysis of the outdoor sources involves characterizing the contaminant concentrations with respect to wind speed and direction as shown in Figure 106 for SO_2 at the Genesee air station. The figure shows a surface that represents the average SO_2 readings taken at the Genesee monitoring station during the program period. As the figure shows, there were significantly higher average levels of SO_2 at the monitoring station when the wind was from the northwest at moderate and high wind speeds. The increase in SO_2 levels when winds are from the northwest is likely due to SO_2 emissions from any industries and communities which are located in that direction. The impact of local emissions of SO_2 is defined in the part of the figure that shows the wind at lower speeds which shows levels higher than the levels at higher wind speeds. The impact of background levels was is shown by the low concentration in the area of the figure with high wind speeds in directions other than the northwest direction.

The information in the three dimensional wind diagrams is combined with wind frequency data from the wind rose diagrams in Figures 14 to 16 to provide an estimate of the source apportionment between local, regional, and background sources. The estimates of the outdoor source apportionment are as follows:

- Portion of a contaminant level due regional sources = (time weighted contaminant level due to regional sources) / (time weighted total SO_2 levels).
- Portion of a contaminant level due local sources = (time weighted contaminant level due to local sources) / (time weighted total SO_2 levels).
- Portion of a contaminant level due background sources = (time weighted contaminant level due to background sources) / (time weighted total SO_2 levels).

The outdoor sources were apportioned for each contaminant that was measured at the three monitoring stations and are listed in Table 72. At the bottom of this table, the average breakdown from the three monitoring stations is shown. A discussion of exposure sources by contaminant follows in the next sections of the report.

Table 72: Summary of Outdoor Exposure Source Apportionment

Monitoring Station	Contaminant	Source		
		Local	**Background**	**Regional**
Genesee	NO2	54%	27%	19%
	SO2	36%	19%	45%
	O3	0%	97%	4%
	$PM_{2.5}$	17%	82%	1%
Wagner	NO2	63%	32%	5%
	SO2	53%	34%	14%
Meadows	NO2	50%	38%	13%
	SO2	24%	44%	32%
Average	NO2	56%	32%	12%
Average	SO2	38%	32%	30%

13.1 Sulfur Dioxide (SO_2)

Figures 106 to 108 show the average SO_2 levels during the period of the program as measured at the three monitoring stations. The elevated levels at higher wind speeds in the figures are indicative of important regional sources impacting the monitoring sites. The figures show somewhat higher concentrations of SO_2 occur at low wind speeds relatively consistent for all directions. This pattern is indicative of local sources impacting the monitoring sites.

Table 72 shows the estimated impact of the local, regional, and background sources at the three monitoring sites. These estimates were derived by combining the data in the Figures 106 to 108 with the wind frequency information from the wind rose diagrams in Figures 14 to 16. The table show the average impact at the three sites is roughly the same for local, background, and regional sources. The pattern of SO_2 concentrations shows that the impact of the local sources is similar to the regional and background sources.

Figure 106: Average SO_2 Levels at the Genesee Air Monitoring Station (January 2004 to December 2004) plotted by Wind Speed and Wind Direction

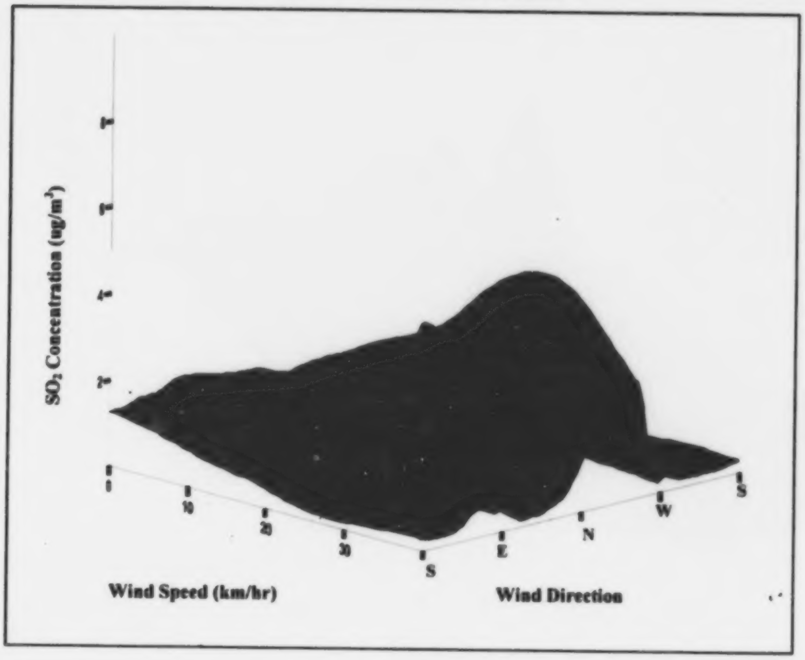


Figure 107: Average SO_2 Levels at the Wagner Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction

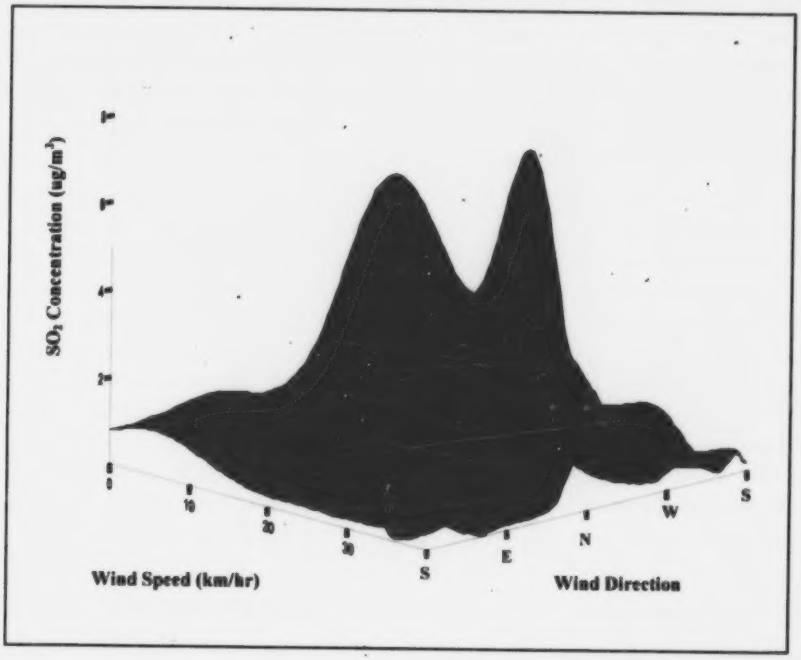
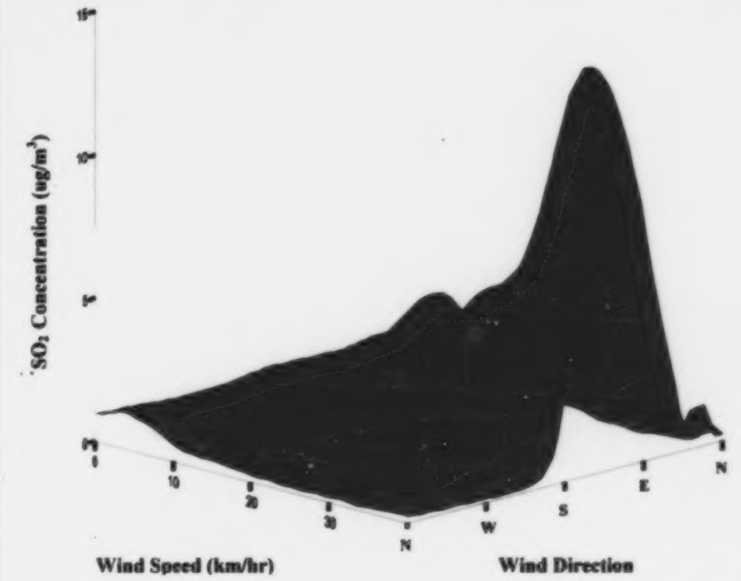


Figure 108: Average SO_2 Levels at Meadows Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction



13.2 Nitrogen Dioxide (NO_2)

Figures 109 to 111 show the average NO_2 levels during the period of the program as measured at the three monitoring stations. The elevated levels higher wind speeds in the figures are indicative of important regional sources impacting the monitoring sites. The pattern of high concentrations of NO_2 occurring at low wind speeds relatively consistent for all directions is common between the three monitoring sites. This pattern is indicative of local sources impacting the monitoring sites with the Meadows site showing the highest levels which were roughly twice that of the other sites at low wind speeds.

Table 72 shows the estimated impact of the local, regional, and background sources at the three monitoring sites. These estimates were derived by combining the data in the Figures 109 to 111 with the wind frequency information from the wind rose diagrams in Figures 14 to 16. The table shows that the impact of the local sources is the dominant influence on the NO_2 concentrations at the monitoring stations. The reason the regional sources were not more important was because of the infrequency of the wind conditions associated with these sources. An example of this is the NO_2 concentrations at the Wagner monitoring site, were it appears from Figure 110 that there are important spikes in concentration at 20 kph in the south-southeast direction. This spike is not important to the overall concentrations at the Wagner site because the associated wind condition occurs less than 1% of the time (see wind rose Figure 14). The NO_2 concentrations in the figures and the associated wind frequencies indicate that ambient NO_2 levels in the Wabamun area are dominated by local sources with background sources accounting for 32% and regional sources accounting for 12%.

Figure 109: Average NO_2 Levels at Genesee Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction

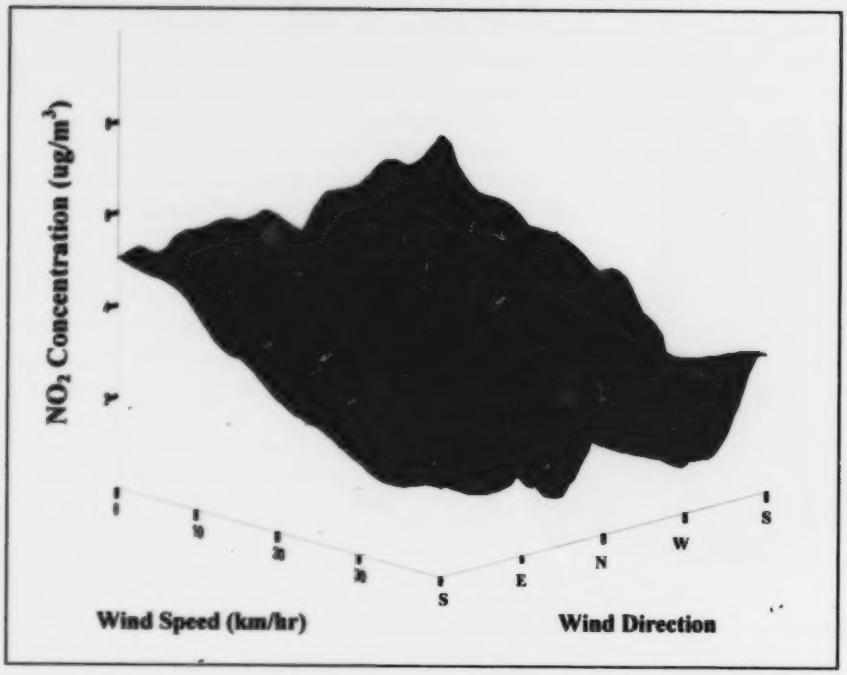


Figure 110: Average NO_2 Levels at Wagner Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction

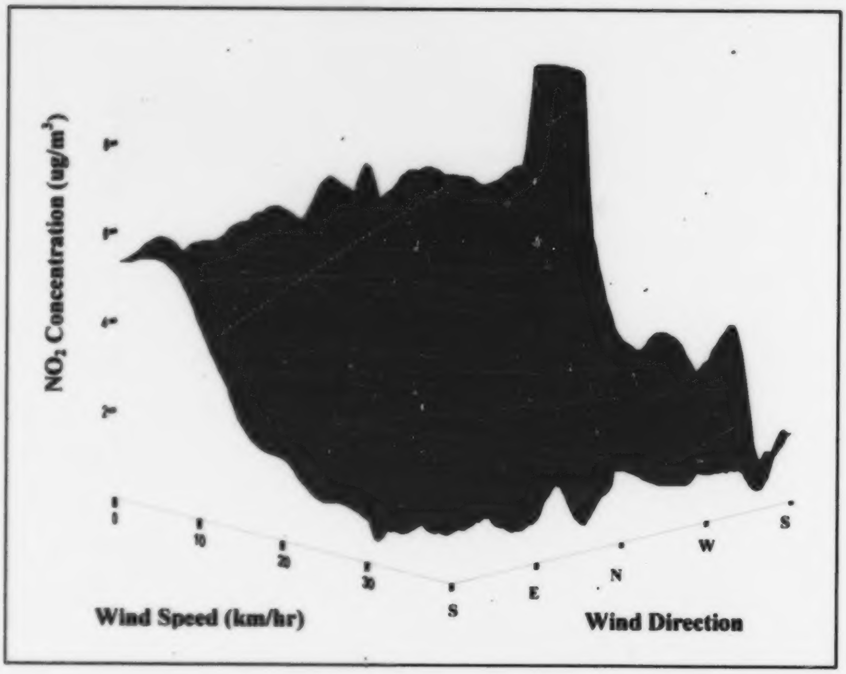
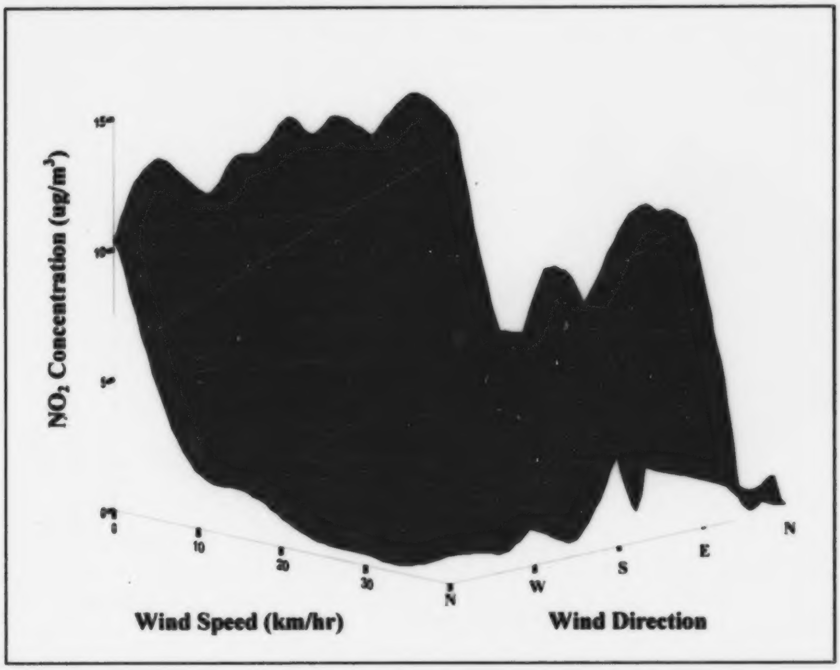


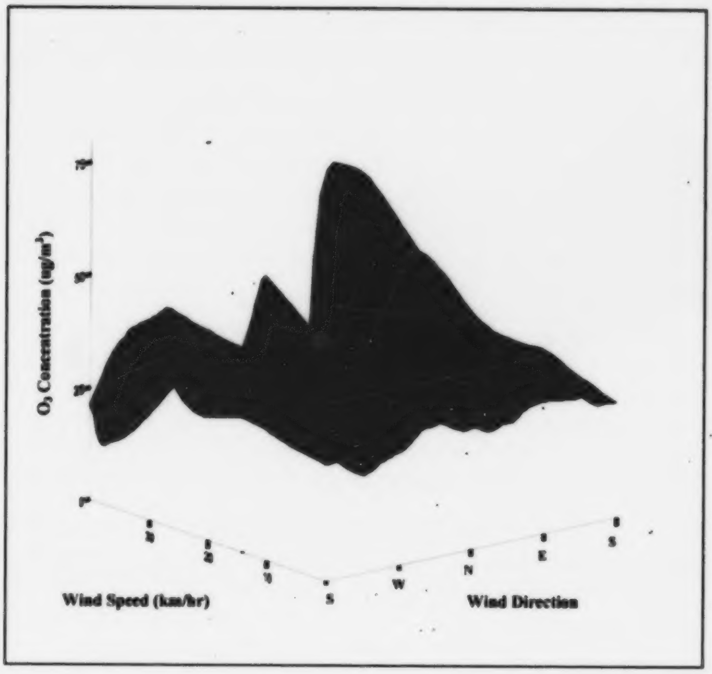
Figure 111: Average NO_2 Levels at Meadows Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction



13.3 Ozone

Figure 112 shows the surface representing the average ozone levels during the program with similar levels at low and high wind speeds in all direction except southeast were the highest levels of ozone occurred during higher wind speeds. These ambient levels did not predict personal exposures well (as shown in Figures 24 to 26). This figure does not demonstrates the classic characteristics of ozone in urban areas where there are lower concentrations of ozone due to scavenging by urban pollutants during low wind speeds (low winds coincides with higher pollutant concentrations) and higher concentrations of ozone coincidental with lower urban pollution during high wind speeds. The figure reflects the fact that the area is not densely populated and local pollution was not an important influence on the ozone levels. The high ridge in the southeast direction at high wind speed likely shows the impact of emissions from the City of Edmonton on the ozone levels at the Genesee monitoring site. Interestingly, Table 72 lists the impact of these increased ozone levels at only 4% on the time weighted ozone concentrations at the site due to the infrequent nature of the associated wind condition. The dominant outdoor source for ozone concentrations at this site was background levels at 97%. Local sources of ozone could not be identified.

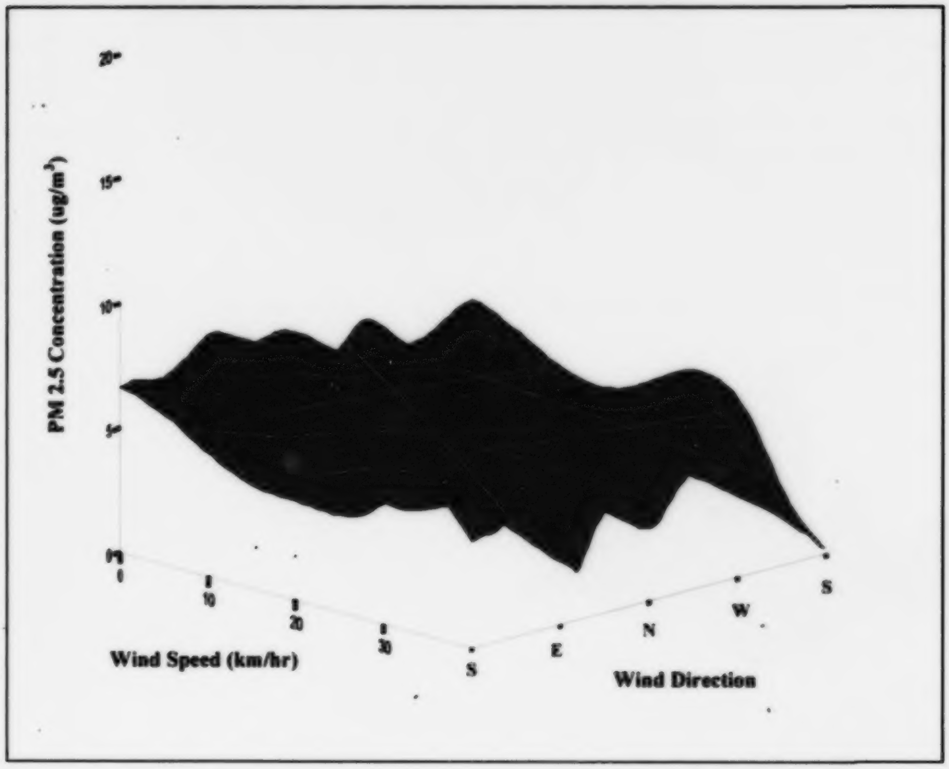
Figure 112: Average O_3 Levels at Genesee Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction



13.4 $PM_{2.5}$

Figure 113 shows the surface representing the average $PM_{2.5}$ levels during the program with levels at low wind speed slightly higher than the levels at high wind speeds in all directions. There were no significant regional sources identified in the figure. These ambient levels did not predict personal exposures well (refer to particulate matter section). Table 72 lists the impact of the sources on the $PM_{2.5}$ levels and shows that background levels were the dominant source responsible for 82% of the time weighted $PM_{2.5}$ concentrations at the Genesee site. Local sources were found to be responsible for 17% and regional sources could not be identified.

Figure 113: Average $PM_{2.5}$ Levels at Genesee Air Monitoring Station (January 2004 to December 2004) Plotted by Wind Speed and Wind Direction



14.0 Conclusions

The goal of the Wabamun and Area Community Exposure and Health Effects Assessment Program was designed to explore the relationship between air quality and human health outcomes. This program collected a wide range of measures of health using both self-reported information and quantitative measures of health. Exposure levels to airborne chemicals and particulates were measured in a variety of locations and the relative contribution of various exposure sources and pathways to airborne chemicals was estimated. Finally, associations between the exposure data and human health effects were described. The key findings of the program are presented in the following sections.

14.1 The Program Sample

Initial targets for recruitment were 300 people from within the program boundaries. Despite numerous recruitment strategies, only 196 individuals volunteered for participation of which 151 provided a complete set of measures for inclusion into the required analyses. The sample demographics were divided into two subgroups, urban/rural (101 participants) and Paul First Nation (50). In general, both subgroups reflected the population in terms of age, but a larger percentage of the sample were female, and had a lower education level compared to the rest of the population. Over half of the urban/rural sample had a household income of $60,000 or more, however a high percentage of participants from Paul First Nation reported a household income of $39,999 or less. It is important to note that almost one-fifth of the Paul First Nation participants indicate they were not employed at the time of participation.

In the survey questionnaires completed by the participants the amount of exposure to tobacco smoke was determined. At the time of the program, 10.9% of the urban/rural participants currently smoke whereas 64.5% of the Paul First Nation participants are current smokers. Of those who are or were smokers, 40.7% of the urban/rural participants versus 78.0% of the Paul First Nation smoke between one (1) and thirty (30) cigarettes per day. A high percentage (78.2%) of urban/rural participants indicated no exposure to second hand smoke versus 37.1% participants from Paul First Nation having no exposure to second hand smoke.

The majority of urban/rural participants reported that they consumed more than five servings of fruits and vegetables per day, however, fewer than recommended number of servings of grain products. Many of the participants from Paul First Nation did not meet the recommended servings as described in *Canada's Food Guide to Healthy Eating*. Also, over 60% of participants from either subgroup had a body mass index (BMI) of 25 or higher which indicates these participants may be overweight. In addition, a high proportion of both subgroups were not as physically active as recommended by Health Canada.

The length of residency of both subgroups was determined from their residential history. For the urban/rural sample, 49.5% of the sample resided in the program area for less than 10 years. Participants from the Paul First Nation indicated longer residency periods with 63% indicating living in the Wabamun area for over 15 years.

14.2 Measures of Exposure

An exposure model was developed to describe the effects of nine factors on personal exposure. These nine factors were: 1) gender; 2) reside at Paul First Nation, 3) urban-rural location; 4) housing characteristics; 5) presence of a garage; 6) job status; 7) smoking characteristics; 8) time activity pattern; 9) outdoor concentration levels; and 10) indoor concentration levels.

The following describes the major findings of the air quality investigation both in terms of the concentrations measured and the factors affecting the variations in personal exposure.

Nitrogen Dioxide (NO_2)

Levels were low compared to existing guidelines and were comparable to other similar studies. Median concentrations were 8.1 µg/m^3 (personal), 6.8 µg/m^3 (indoor), and 5.8 µg/m^3 (outdoor). The final model predicted about 57% (47% adjusted) of the variation in personal NO_2 exposure across individuals. Indoor variation accounted for over one-half of the variation in personal NO_2 exposure described by the model. Time activity was also an important driver of personal exposure while smoking, outdoor levels and housing characteristics had smaller effects.

Sulfur Dioxide (SO_2)

Indoor and outdoor levels were very low compared to existing guidelines. Median concentrations were 0.80 µg/m^3 (personal), 0.6 µg/m^3 (indoor), and 2.6 µg/m^3 (outdoor). The final model predicted about 34% (22% adjusted) of the variation in personal SO_2 exposure across individuals. Overall, indoor levels directly account for half the variation in personal exposure. Time activity also affected personal exposure as well having a garage.

Ozone (O_3)

Indoor and personal levels of ozone in the Wabamun area were amongst the lowest in the CEHEAP studies. Outdoor levels greatly influenced the level of personal and indoor exposure as well being lower than relevant guidelines. Median concentrations were 3.2 µg/m^3 (personal), 1.6 µg/m^3 (indoor), and 43.9 µg/m^3 (outdoor). The final model predicted about 72% (67% adjusted) of the variation in personal O_3 exposure across individuals. The variation in personal exposure described by the model was mostly due to indoor levels directly and time activity and outdoor levels acting through indoor levels to affect personal exposure. Time activity patterns were an important variable predicting exposure and likely the most important factor is how much time was spent outdoors. It is possible that the direct effect from smoking is due to additional time spent outdoors.

Volatile Organic Compounds (VOCs)

All the volatile organic compounds (VOCs) investigated in this program except nonane demonstrate a pattern of exposure which shows the variation in indoor air levels dominates personal exposure and accounts for at least half of the variation explained by the model. Exposure to nonane was directly affected by being a Paul First Nation resident operating through indoor levels to affect personal exposure.

Decane, methylhexane, nonane, *N*-propylbenzene and toluene showed exposure indirectly influenced by being Paul First Nation resident by impacting indoor levels. *M,-p*-xylene, heptane, ethylbenzene, decane *o*-xylene showed personal exposure was affected by outdoor levels acting through indoor levels. Outdoor levels of these VOCs were low or not detected and indoor levels generally mirror rates of personal exposure. This indicates that exposure to these VOCs arise from consumer goods, products or activities occurring within the homes of Paul First Nation residents.

Contact with tobacco smoke and having an attached garage were also important factors associated with personal exposure to some of the VOCs. It should be emphasized that all of these factors are minor in comparison to indoor concentration levels.

Particulate Matter 2.5µm ($PM_{2.5}$)

$PM_{2.5}$ outdoor concentrations measured in Wabamun were similar with that found in other communities in that they were well below guidelines. Median concentrations were personal (28.7 µg/m^3), indoor (10.7

μg/m^3), and outdoor (6.5 μg/m^3). Variability in smoking operating directly and indirectly through indoor levels was the dominant factor affecting $PM_{2.5}$ exposure. Garage characteristics operating directly and indirectly through job status was also and important factor. Variations in outdoor concentrations were not important factors affecting variations in personal exposure to $PM_{2.5}$.

Due to equipment problems the real time data was not collected for the polyaromatic hydrocarbons (PAH) of this program initiative. Without the real time data, the small number of integrated samples collected did not provide the statistical power necessary to make meaningful conclusions and as a result this analysis was not undertaken.

Exposure Sources

- Ambient concentrations were not a good predictor of personal exposures to nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3) and $PM_{2.5}$. This was first noted in exposure modeling in Section 8.
- The most important exposure source of nitrogen dioxide (NO_2) was identified as local sources which were estimated as being responsible for 56% of time averaged exposure. The background and regional sources contribution to exposure were estimated at 32% and 12%, respectively. While there appear to be important regional sources, the impact on exposure is limited by wind patterns.
- The local, regional and background exposure to sulfur dioxide (SO_2) were equally important.
- Exposure to ozone (O_3) in this program area is dominated by background sources which account for 97% of the impact. Significant local and regional source was not detected in the analysis.
- $PM_{2.5}$ was only measured at the Genesee site. Background levels were the dominant source responsible for 82% of the time weighted concentrations at the Genesee sites. Local sources were found to be responsible for 17% and regional sources could not be identified

14.3 Measures of Health

Biomarkers of Exposure

The biomarkers of exposure were included to provide evidence of exposure to a variety of contaminants. Seven biomarkers were quantified for and include: nicotine, mercury, arsenic, benzene, toluene and xylene. To conduct this analysis, participants submitted blood, urine and hair samples. The values of the biomarkers of exposure measured in this program were lower than those measured in other places. Biomarkers for xylene and ethylbenzene were not detected in any of the participants' samples.

Biomarkers of Effect

Biomarkers of effect were evaluated in three separate components of the program. The first component, serum IgE was related to cigarette smoking, a history of asthma and wheezing near trees but not to pets in the household, smoking during pregnancy or birth order. Although there was a relationship between serum IgE and FEV_1 and FVC, this was not significant for the sample as a whole but was marginally significant for members of the urban-rural sample. The Paul First Nation participants had "super-normal" lung function, confirming that standards used for normalizing lung function for aboriginal populations may not always be appropriate.

The second component, autoantibodies, did identify a higher prevalence of positive ANA results. However, in this sample population there were a high proportion of women, individuals over 40 and those suffering from colds and flus when they provided samples. Further analysis into environmental agents and a health record analysis revealed the Wabamun program area did not have significantly different levels of autoimmune disease in comparison to other communities. It should be noted that participants with disease specific autoantibodies were notified of their results and advised to consult their family physician for further information.

All participants completed five (5) spirometric sessions to determine their lung function. Lung function is the third component of measuring for biomarkers of effect in the CEHEAP studies. The results from the spirometric sessions are compared to normal values based on a participant's age, height, and gender. These calculated values determined that the lung functions of the participants were within the normal range for both forced vital capacity (FVC) and forced expiratory volume.

Self Reported Health

Several standardized questionnaires were included to obtain measures of the participant's perceived health, as well as measures of mental and psychosocial health. No statistically significant differences between the samples were identified on any of the self-reported health questionnaires. The most common diagnoses in Wabamun included back problems and other allergies, with reported rates of 27.9% and 21.5%, respectfully. Over twenty percent (22.7%) reported no diagnosis at the time of the survey.

Health Records

Findings from the analysis of health records suggest the following:

- There is no evidence of either a significantly higher morbidity (period prevalence, frequency of visits) of asthma, bronchitis, and COPD in the Wabamun and area, nor an increased risk of death from all causes, respiratory disorders, COPD, and major cardiovascular diseases in this area.
- There is evidence of an increased prevalence and frequency of visits for all respiratory disorders combined in the Wabamun and area. However, the mean visits of asthma and COPD are lower when compared to other CEHEAP communities.
- There is a difference in the Fee-For-Service physician visits for overall illness between the program participants and non-participants. Overall illness refers to any type of illness or access to any type of health care service.

15.0 Abbreviations

AENV – Alberta Environment

AHCIP – Alberta Health Care Insurance Plan

BTEX – benzene, toluene, ethylbenzene, and xylenes

BMI – Body mass index

CASA – Clean Air Strategic Alliance

COPD – Chronic obstructive pulmonary disease

DNA – Deoxyribonucleic acid

FFS – Fee-for-Service

GHQ – General Health Questionnaire

I/O – Ratio of indoor exposure to outdoor exposure

L – Litres

MDL – Method detection limit

MSG-PM/O_3 – Alberta Multi-Stakeholder Group on Particulate Matter and Ozone

N – Number of cases overall

NES2 – Neurobehavioral Evaluation System

NO_2 – Nitrogen dioxide

O_3 – Ozone

P/I – Ratio of personal exposure to indoor exposure

$PM_{2.5}$ – Particulate matter of 2.5 microns or less (approximately 1/20 the diameter of a human hair); also called fine particles

P/O – Ratio of personal exposure to outdoor exposure

RHA – Regional Health Authority

SD – Standard deviation

SES – Socio-economic status

SO_2 – Sulfur dioxide

TEAM – Total Exposure Assessment Methodology

UK – United Kingdom

USEPA – United States Environmental Protection Agency

VOCs – Volatile organic compounds

WMS-R – Wechsler Memory Scale – Revised

16.0 Definitions

Benzene[204]

- A water-soluble volatile organic compound (VOC) which at normal temperatures is a liquid, but readily evaporates and small amounts are detectable in the atmosphere.
- Important sources are the combustion of petroleum fuels by motor vehicle engines and emissions associated with many industrial activities such as ore mining, wood processing, coal mining, textile manufacture, and processes used in the oil and gas industry.
- Other sources, of which cigarette smoking is a major one, make important contributions to the exposure of individuals.
- Benzene is a known carcinogen and appears on Health Canada's First Priority Substances List.

Biomarker

- A specific biochemical in the body which has a particular molecular feature that makes it useful for indicating environmental exposure, the progress of disease, or the effects of treatment.

Body Mass Index (BMI)

- A measure of body mass which is calculated from a person's reported weight and height. It is calculated by using the following formula:
  Using Metric System: weight (kg) / [height (m)]^2
  Using Imperial system: weight (lb) / [height (in)]^2 x 703
- Used as a screening tool to identify *potential* weight problems for adults, but must be taken into consideration with other assessments (i.e. skin thickness, diet, level of physical activity) to determine if a person's weight is a health risk.

BTEX compounds

- The BTEX chemicals (benzene, toluene, ethylbenzene, and xylenes) are volatile organic compounds (VOCs) which are commonly found together in crude petroleum and petroleum products such as gasoline.
- They are also produced as bulk chemicals for industrial use as solvents and starting materials for the manufacture of pesticides, plastics, and synthetic fibers.

Decane[205]

- Colourless liquid with a gasoline like odour. Its vapour is heavier than air and may spread long distances and accumulate in low-lying areas. In its liquid form it can float on water and may travel long distances and or spread fire.
- Component of gasoline, jet fuel, kerosene and petroleum solvents such as white spirit; solvent; rubber industry; paper industry and a constituent of polyolefin manufacturing wastes.

Empirical

- Based on observation and experience.

Ethylbenzene

- A water-soluble volatile organic compound (VOC)
- Ethylbenzene is used primarily in the production of styrene; other uses include solvents in paints and varnishes, as products in synthetic rubber, household cleaning products, gasoline, pesticides, carpet glues, asphalt, and tobacco smoke.
- Ethylbenzene enters the atmosphere primarily from emissions and exhaust connected with its use in gasoline; more localized sources will be emissions, waste water, and spills from its production and industrial use.

Health Canada's First Priority List[206]

- The Canadian Environmental Protection Act (CEPA) authorizes the Minister of the Environment and of Health to investigate a wide variety of substances that may be present in the environment and cause adverse effects on the environment or on human health.
- This list includes 44 substances which are assessed to be "toxic or capable of becoming toxic". In this program, benzene, xylene and toluene were assessed and are on this priority list.

Heptane & Methylhexane[207]

- Methylhexane is an isomer of heptane as it has the same chemical formula as heptane but the atoms in the model are arranged differently.
- Both are a colourless liquid with a gasoline odour.
- Heptane is used as a solvent in glues, varnishes, cements and inks; used to extracting natural oils and fats; a major ingredient in gasoline and aviation fuel and in petroleum solvents such as petroleum naphtha and rubber solvent.
- Methylhexane is commonly found in paint and solvents.

Hexane[208]

- A volatile organic compound which colourless in its liquid state and has a mild, gasoline – like odour. It is both naturally and synthetically produced.
- Minor constituent of crude oil and natural gas, but also used in the extraction of vegetable oil from seeds such as safflower, cotton, soy bean and flax.
- Also used as a cleaning agent for textiles, furniture and leather industries.

Limonene[209]

- A type of volatile organic compound which is classified as a terpene. Terpenes are produced primarily by plants in the form of an essential oil.
- Colourless liquid at room temperature that takes its name from lemon, as it smells like this citrus fruit.
- Used in food manufacturing as flavouring and added to cleaning products such as hand cleaners and polishes to give a lemon-orange fragrance.
- Increasingly being used as an environmentally alternative to mineral oils as a solvent for cleaning purposes, such as the removal of oil from machine parts, being more easily biodegradable than mineral oils and produced from a renewable source.

Median

- The value halfway through an ordered data set, below and above which there lies an equal number of samples.

Method Detection Limit (MDL)

- The minimum concentration that can be measured and reported with confidence that the value is above zero -- that is, that the contaminant is actually present.
- In this program, three standard deviations above the mean method blank levels were used as the MDL.

Morbidity

- The condition of being diseased or sick; a state of ill-health.

***N*-butylbenzene**

- A colourless volatile organic compound (VOC) with an aromatic odour, sometimes resembling an alcoholic odour.
- Used as a speciality solvent; production in other chemicals; insecticides; printing, painting; perfume and as a base ingredient and in the production of Ibuprofen.

***N*-propylbenzene**[210]

- A colourless volatile organic compound (VOC) with no detectable odour.
- Naturally found in petroleum and bituminous coal. It is released to the atmosphere in emissions from combustion sources such as incinerators, gasoline engines and diesel engines. Solvent evaporation, land filling leaching and general use of asphalt also releases it into the environment.
- Used in building and construction plastic form insulation, including pipe and block; other rubber floor and wall covering; scatter rugs and bathmats and sets; sheet vinyl flooring; wood office work surfaces (modular systems).

Nonane[211]

- A volatile organic compound (VOC) which is colourless liquid with a gasoline like odour.
- Used as a solvent; important component of gasoline and petroleum solvents; manufacture of paraffin products; paper processing and rubber industry; synthesis of biodegradable detergents; jet fuel research and distillation chaser.

Nitrogen Dioxide (NO_2)[212]

- For the purposes of air quality monitoring, oxides of nitrogen (NO_X) is considered to be the sum of nitric oxide and nitrogen dioxide; most oxides of nitrogen are emitted in the form of nitric oxide which will rapidly react with ozone in the atmosphere to form nitrogen dioxide.
- In Alberta, about 43% of oxides of nitrogen emissions are produced by transportation (primarily by vehicles), while 37% are due to industrial sources (oil and gas industries) and 18% as a result of power plants (based on 1990 emission estimates).
- Smaller sources of oxides of nitrogen include natural gas combustion, heating fuel combustion, and forest fires.

Odds Ratio

- Odds are the number of times an event is expected to occur *(a)* divided by the number of times it is expected not to occur *(b)* or *a/b*. This contrasts with the probability of an event defined as the number of times an event is expected to occur divided by the number of times it could have occurred, or *a/(a+b)*.
- An ***odds ratio*** is a ratio of the odds of an event occurring in one group divided by the odds of it occurring in another group. As the odds ratio deviates from 1.0 (indicating equal odds in the two groups), the larger is the disparity between the groups.

Octane[213]

- A colourless volatile organic compound (VOC), normally found in a liquid state at normal temperatures.
- Used in aerosol paint concentrates, eye preparations (mascara, eye shadow, eye liners), furniture polish and cleaners; laundry starch preparations; lubricating oils; all types of paint and paint thinners; wood office furniture and work surfaces (modular systems)

Ozone (O_3)[214, 215]

- Ozone is both a naturally occurring gas, generated in the higher layers of the atmosphere and a major constituent of photochemical smog.
- Unlike other pollutants, ground-level ozone is not emitted directly by man's activities, but is generated by a photochemical reaction of oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) in the presence of sunlight.
- In Alberta, ozone concentrations are generally lower at urban locations than at rural locations due to the destruction of ozone by nitric oxide which is emitted by vehicles.
- In Alberta, maximum ozone values are generally recorded during the spring and summer months.

Particulate Matter (PM)[216]

- Particulate matter consists of a mixture of particles of varying size and chemical composition.
- Most man-made particles are in the range of 1 to 10 microns in diameter; particles less than 10 micrometers in diameter (PM_{10}) are considered to be inhalable particulates and are suspended in the air for an indefinite period of time.
- PM_{10} sources, which can be inhaled into the nose and throat but do not normally penetrate into the lungs, include windblown soil, road dust, dust resulting from other activities (e.g. harvest), and industrial processes, generally created during burning processes, consisting of fly ash from power plants, carbon black from diesel and gasoline engines, and soot from wood-burning.
- This program quantified the finer particles ($PM_{2.5}$ and less), which can penetrate into the lungs (respirable particulates), are typically secondary aerosols that form when chemical reactions occur between sulfate (from power plants) or nitrate (from motor vehicles and industry such as oil and gas plants) and ammonia or from sources such as compressor stations, household heating appliances, and forest fires.

Relative Risk

- Ratio of at-risk individuals to those not at risk in a group; ratio of a disease rate in the program population to the rate in the reference population.
- **Adjusted relative risk:** ratio of a disease rate in the study population to the rate in the reference population when effects of confounding are taken into consideration.

Sulfur Dioxide (SO_2)[217,218]

- A water-soluble irritant gas and a major pollutant in the atmosphere formed during the processing and combustion of fossil fuels containing sulfur, for example from gas plant flares, oil refineries, pulp and paper mills, fertilizer plants, coal-fired power plants, power generating stations, metal smelters, and heating boilers.
- Sulfur dioxide (along with NO_X) has a number of other environmental effects including lake acidification due to acid rain, and associated corrosion of stone and metalwork.
- Sulfur reacts in the atmosphere to form sulfuric acid and acidic aerosols which contribute to acid rain; combines with other gases to produce aerosols which may reduce visibility causing haze over large regions.
- In Alberta, it is estimated that 42% of sulfur dioxide emissions are emitted by natural gas processing plants while oil sands and power plants produce 26% and 18%, respectively, based on 1990 emission inventory.

TEAM - Total Exposure Assessment Methodology

- Method developed by the USEPA to determine exposures of the general population to certain pollutants.

Toluene

- A water-soluble volatile organic compound (VOC).
- The largest chemical use for toluene is in the production of benzene and urethane; also used as a solvent, gasoline additive, and in the manufacture of explosives, dyes, cements, spot removers, cosmetics, antifreezes, asphalt, and detergent.
- Toluene is released into the atmosphere principally from the volatilization of petroleum fuels and toluene-based solvents and thinners, and from motor vehicle exhaust.
- Toluene appears on Health Canada's First Priority Substances List.

Volatile Organic Compounds (VOCs)

- Several thousand chemicals both synthetic and natural which contain carbon and hydrogen. Over 900 have been identified in indoor air, with over 250 recorded at concentrations higher than 1 ppb.
- VOCs produce vapors readily; at room temperature and normal atmospheric pressure, vapors escape easily from volatile liquid chemicals.
- VOCs include gasoline, industrial chemicals such as benzene, solvents such as toluene and xylene, VOCs can be emitted naturally or as by-products of industrial processes.
- In this program, sampling was undertaken for 14 different VOCs.

Xylene (*m*-,*p*-Xylene & *o*-Xylene)[219]

- A water-soluble volatile organic compound (VOC)
- Major environmental releases of xylenes are due to emissions from petroleum refining, chemical plants, automobile exhaust and volatilization when used as a solvent.
- Used in a variety of consumer products including gasoline, paint, paint thinners and removers, varnish, shellac, rust preventatives and cigarette smoke.
- Xylene appears on Health Canada's First Priority Substances List.

17.0 Endnotes

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Appendix A

Children's Biomarkers of Exposure

1.0 Introduction

The children's component was a pilot project added to Wabamun Community Exposure and Health Effects Assessment Program. This component was added as community stakeholders had a high degree of interest in the potential exposure effects children may be experiencing. As children are still in a developmental stage of their life and may have higher rates of exposure due to higher metabolism and greater contact with outdoors then adults. It is important to include children because they are more sensitive and may respond differently to environmental substances.

In order to have child participants, ethical approval was required from the University of Alberta/Capital Health and Health Canada Research Ethics Boards. Within this approval, strict To be considered eligible, participants must be between the ages of 10 -12, reside and attend school within the study boundaries for at least one year and written consent from either parent/guardian must be received. Child participants did not wear personal exposure monitors instead exposure was determined by biological sample donations. Each participant was asked to donate blood, urine and hair samples which were analyzed the same as adult samples.

2.0 Sample Size and Recruitment

A minimum of fifty (50) children would need to be recruited for this pilot study to be considered successful. The targeted distribution was: 25 children from Stony Plain, Spruce Grove and Devon and 25 children from Paul First Nation.

A variety of recruitment strategies were utilized to enroll children in this part of the program. These included field workers at Paul First Nation directly contacting families and by asking adult participants to involve their children in the program ('snowballing). Recruitment packages were provided to local schools in the Blackgold and Evergreen Catholic School Divisions. Prior to access students in these school divisions, permission was received from the school boards.

A separate news release was developed for this section and released to all media within the study area. This was used to try and increase awareness about not only the children's component but the adult program as well. Finally, a private research corporation was contracted to recruit interested parents and children by telephone.

3.0 Characteristics of the Sample

Table A-1 provides information regarding the number of participants who volunteered to be part of the Children's Health Study an additional component in this Community Exposure and Health Effects Assessment Project. While the total number of participants exceeds the minimum sample size required for this component, fewer than anticipated participants were seen from the Paul First Nation.

Table A-1: Number of Children Participants

	Number of Participants (Urban/Rural)	Number of Participants (Paul First Nation)	Total
Total with Complete Data	36	17	53

The age range of children required for this new element was between 10-12 years of age. For the two samples groups, the average age was very similar, 10.9 years (N=51, SD=0.9) for WACEHEAP and for Paul First Nation 11.1 years (N=17, SD=0.7). In the WACEHEAP sample, there were a higher proportion of male children (66.7%) than females, whereas from the Paul First Nation a higher number of female participants (64.7%) were noted.

4.0 Biomarkers of Exposure

This section provides the results of blood, urine and hair samples submitted by the child participants. While a total of 53 children participated in this pilot project, not all the participants completed all components of the program.

Nicotine

Fifty two children provided blood samples for nicotine analysis. Nicotine was not detected in any blood samples. The results indicated that none of the children were active tobacco smokers or were not exposed to tobacco smoke from others shortly before blood samples were donated.

Mercury

A total of 52 children provided blood samples and 53 provided urine and hair samples for mercury analysis. Geometric means of total mercury were 0.7 µg/L in blood and 0.1 µg/g in hair. In a European study, geometric means of total mercury levels were 1.93 – 3.81 µg/L in blood and 0.6-0.96 µg/g in hair for children at age of 7-14 years old[1]. Mean of total urine mercury in this study was 0.7 µg/L. The mean of urinary mercury reported in the literature was 1.2 µg/L for children at age of 6-14 years old.[2]

Blood or hair mercury likely reflects exposure to methyl-mercury from consuming fish and urinary mercury likely reflects exposure elemental or inorganic mercury such as dental fillings. Overall, the total mercury levels measured in the child participants are lower than those reported in the literature. Therefore, the level of exposure to mercury in these participants is lower than children residing in other areas.

Arsenic

A total of 52 children provided blood samples and 53 provided urine samples for arsenic analysis. The average level of total arsenic was 0.25 µg/L in blood. Scientific literature could not provide a measure of total blood arsenic levels for children between the ages of 10-12 years.

Total urinary arsenic and arsenic speciation are listed in Table A-2. Urinary arsenic levels measured in children in our community are similar to the levels reported in the literature. The results indicated that children in our community were exposed to a low level of arsenic from various sources as children living in U.S and Europe.

Table A-2: Mean of Urinary Arsenic Species (µg/L) in Different Studies

Study	Location	Sample Size (Age Range).	Total As	As III + As V	DMA	MMA
Wabamun, 2005	**Canada**	**53 (10-12 yr)**	**9.7**	**0.7**	**4.8**	**0.2**
Kalman et al. 1990[3]	U.S.	133 (7-13 yr)	9.4	1.2	6.7	1.4
Seifert et al. 2000[2]	Germany	731 (6-14 yr)	9.5	-	-	-
Pellizzari and Clayton 2006[4]	U.S.	83 (3-12 yr)	14.4	-	5.5	-

Summary

Three biomarkers of exposure were measured in biological samples in children and are summarized in Table A-3. Nicotine in blood samples was not detected. Total mercury levels in blood, hair and urine samples were similar to the levels reported in children living in other places. Like total mercury, urinary arsenic levels (total arsenic and arsenic speciation) were similar to the levels reported in children living in other places. The results indicated that children in our community were exposed to a low level of mercury and arsenic from various sources similar to children living in other places.

Table A-3: Means and Ranges of Measured Biomarkers of Exposure in Children

Biomarker	Type	Sample Size	Unit	Mean	Min.	Max.	Potential Exposure
Nicotine	Blood	53	ng/ml	N/D*	N/D	N/D	Active tobacco smoke (very short term)
Total Mercury	Blood	52	µg/L:	0.6	N/D	3.3	Methyl-mercury exposure such as fish consumption
	Hair	53	µg/g	0.1	N/D	0.4	
	Urine	53	µg/L:	0.7	N/D	4.9	Inorganic mercury exposure such as dental amalgams
Total Arsenic	Blood	52	µg/L:	0.25	N/D	3.3	Very short term exposure
	Urine	53	µg/L:	9.8	N/D	146	Mainly from food consumption such as seafood and mushroom
Arsenic III	Urine	53	µg/L:	0.09	N/D	2.4	Mainly from water, specifically groundwater
Arsenic V			µg/L:	0.6	N/D	1.7	
Dimethylarsenic			µg/L:	4.5	N/D	17	
Monomethylarsenic			µg/L:	0.2	N/D	1.6	

**N/D: not detected.*

5.0 Biomarkers of Effect

5.1 Immunoglobulin gamma E (IgE)

Results

The mean and log transformed values of IgE in the serum for children are shown in Table A-4. The distribution of total IgE divided into a low level (less than 20), intermediate level (20-99), high (100-399) and very high (more than 400) kU/L is shown in Table A-5. An elevated IgE (greater than 100 kU/L) was seen in 34.6% of the children. The total mean IgE for the children was significantly higher than the mean IgE in the adults.

Table A-4: Total Serum IgE – Children

	Raw Data (kU/L)	Log Transformed Data (kU/L)
Mean	134.942	1.481
Median	27.000	1.431
SE	32.265	0.119
SD	232.670	0.860
N value	52	52

Table A-5: Distribution of Total IgE Serum - Children

IgE (kU/L)	Percent (%)
>400	11.5
100-399	23.1
20-99	21.2
<20	44.2

Table A-6 shows the relationship between the log IgE and a positive ingestant screen for the children. The 9 individuals with a positive response had a significantly greater IgE than the 43 participants with a negative response ($p = 0.032$). The median IgE for the positive responders was 238.0 kU/L compared with a median of 26.0 kU/L in those with a negative ingestant screen.

Table A-6: Ingestant screen - Children

	Positive Response (Log data)	Negative Response (Log data)		Positive Response (Raw data)	Negative Response (Raw data)
Mean ± SE	2.016±0.326	1.369±0.122	Median	238.000	26.000
n-value	9	43		9	43
Statistically significant*	0.032		Statistically Significant*	0.032	

**Mann-Whitney Rank test*

Similar data for the inhalant screen for children are shown in Table A-7. Fourteen (14) individuals had a positive response, whereas 38 had a negative response. Again, the median IgE in the positive responders was significantly greater than those in the negative responders ($p < 0.001$).

Table A-7: Inhalant screen - Children

	Positive Response (Log data)	Negative Response (Log data)		Positive Response (Raw data)	Negative Response (Raw data)
Mean ± SE	2.139±0.262	1.238±0.110	Median	258.000	17.500
n-value	14	38		14	38
Statistically significant*	<0.001		Statistically Significant*	<0.001	

**Mann-Whitney Rank test*

The results of the specific IgE tests for common inhalant antigens are shown in Figures A-1 to A-12 and for the ingestant allergens in Table A-5 located at the end of this appendix. In general, the children show greater reactivity than the adults but the numbers are too small to test for statistical significance.

Discussion

The children showed several significant differences from the adult population. They had significantly greater values for serum IgE and greater reactivity to the inhalant and ingestant allergens used in the screens. These findings are in keeping with other studies that show that IgE is higher in younger individuals and then declines with age[567].

5.2 Autoantibodies

Results

A total of 52 samples were collected for analysis of ANA and some specific autoantibodies. A weakly positive ANA is defined as a value of greater than 1:80 titer. The percentage of samples with a weakly positive ANA was 25% (13/52) in the children's sample.

Since the ANA test is not generally specific enough to identify disease-related autoantibodies, specific tests are often performed to clarify a positive ANA result. The most common disease-specific autoantibodies include U1-RNP, Sm, SS-B, SS-A, dsDNA, centromere protein, chromatin and others as listed in Table A-8.

Table A-8: Autoantibody Specificities

Autoantigen*	Children (N=52)
U1-RNP	0
SS-B	3
SS-A	0
dsDNA	0
Centromere protein	1
Chromatin	1
Nucleolar	7
Mitochondria	0
Jo-1 (histidyl tRNA synthetase)	1
Anti-Scl-70 (topoisomerase I)	1

**Note: Serum samples can have more than one specificity.*

Antibodies to the above antigens are seen in the conditions such as systemic lupus erythematosus (SLE), Sjögren's syndrome (SjS), systemic sclerosis (SSc), rheumatoid arthritis (RA) or underlying inflammatory myopathy. The presence of the autoantibodies in isolation **does not** mean that disease is present and does not invariably predict future autoimmune diseases in healthy individuals. For example, first degree relatives of individuals with these antibodies may carry these autoantibodies for years without any evidence of disease. Medical evidence suggests that an additional immune trigger is required to initiate disease expression and this may explain recent medical evidence showing that some individuals with specific autoantibodies may develop clinical signs and symptoms over protracted years of observation[8,9]. Therefore, all test results must be interpreted in conjunction with clinical data such as the individual's history, physical examination and other laboratory data.

Summary

For meaningful interpretation of ANA results on a population level, a comparative group of participants needs to be available. As such a comparative group is not available; it is difficult to determine if these results deviate from the norm. In addition, unlike the adult participants, children who submitted samples for analysis did not provide information about current or underlying disease states or symptoms. Therefore, providing a clear understanding of why these autoantigens were detected is not possible without follow-up samples and investigation.

6.0 Additional Information

Table A-9: Specific Ingestant IgE Reactivity - Children (N=9)

Score	Eggs n (%)	Milk n (%)	Peanut n (%)	Wheat n (%)	Codfish n (%)	Soya n (%)
0	6 (66.7)	5 (55.6)	5 (55.6)	5 (55.6)	7 (77.8)	5 (55.6)
1	2 (22.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (11.1)	1 (11.1)
2	1 (11.1)	2 (22.2)	1 (11.1)	3 (33.3)	1 (11.1)	2 (22.2)
3	0 (0.0)	2 (22.2)	2 (22.2)	1 (11.1)	0 (0.0)	1 (11.1)
4	0 (0.0)	0 (0.0)	1 (11.1)	0 (0.0)	0 (0.0)	0 (0.0)
5	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Note: Due to small cell counts, interpret with caution

Figure A-1: Cat Dander Reactivity, Children (N=14)

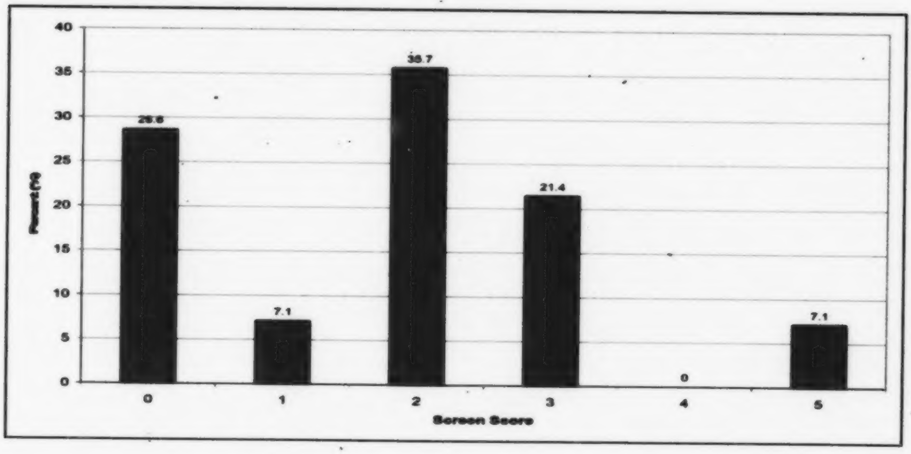


Figure A-2: Dog Dander Reactivity, Children (N=14)

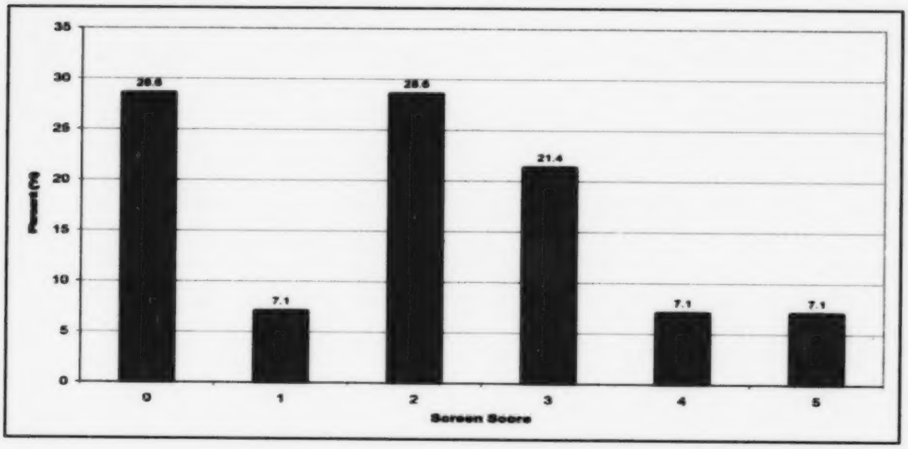


Figure A-3: Dermataphagoides Pteronyssinus Reactivity, Children (N=14)

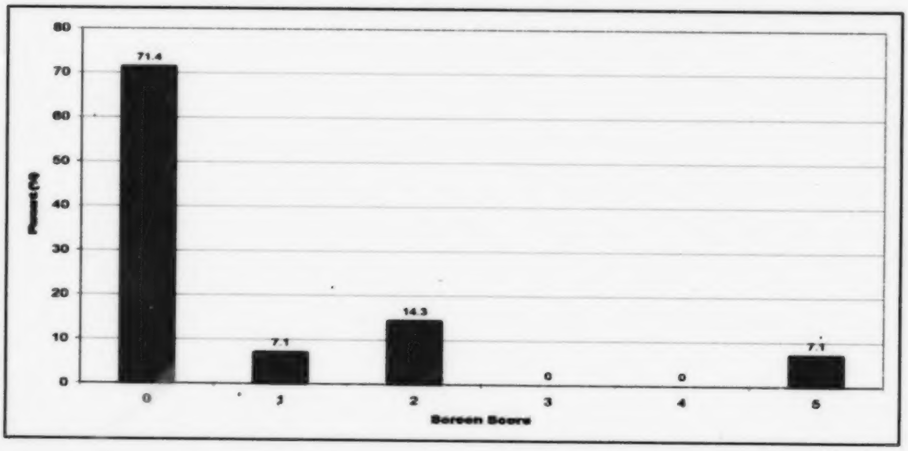


Figure A-4: Hollister Stier Reactivity, Children (N=14)

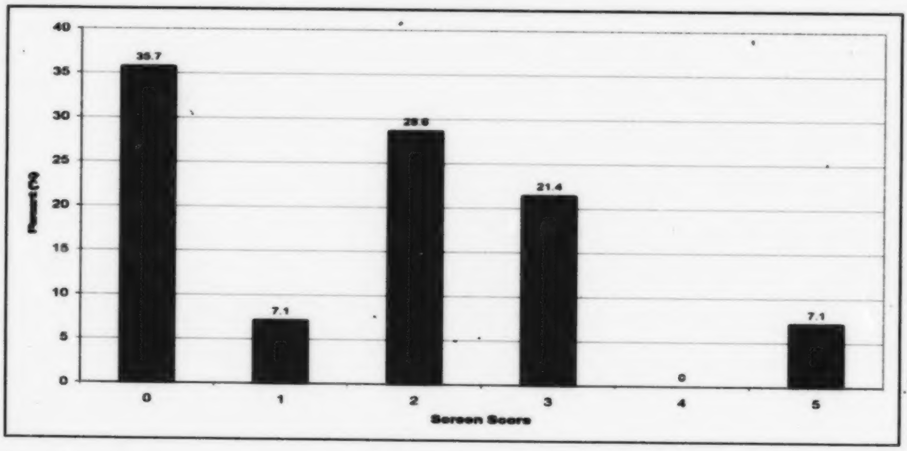


Figure A-5: Timothy Grass Reactivity, Children (N=14)

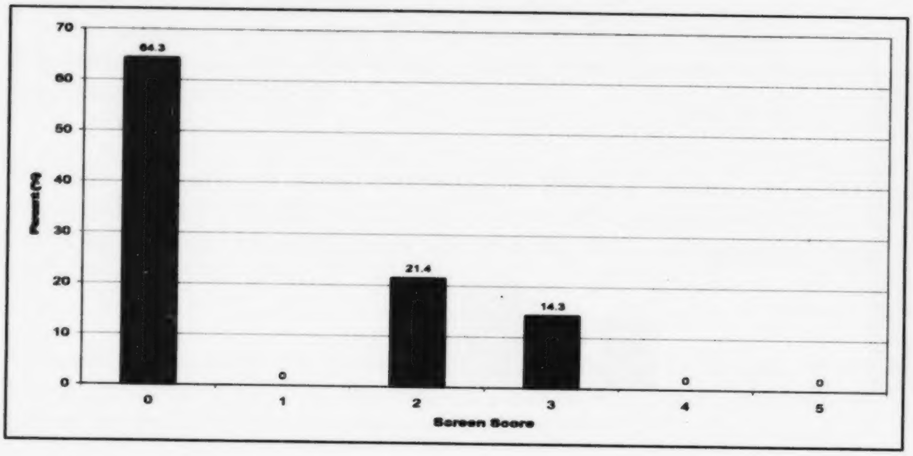


Figure A-6: Alternaria Tenius Reactivity, Children (N=14)

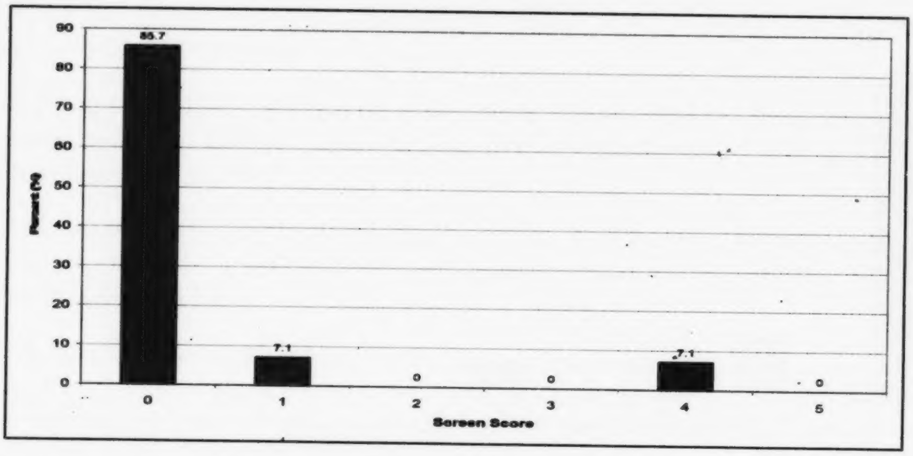


Figure A-7: Birch Pollen Reactivity - Children (N=14)

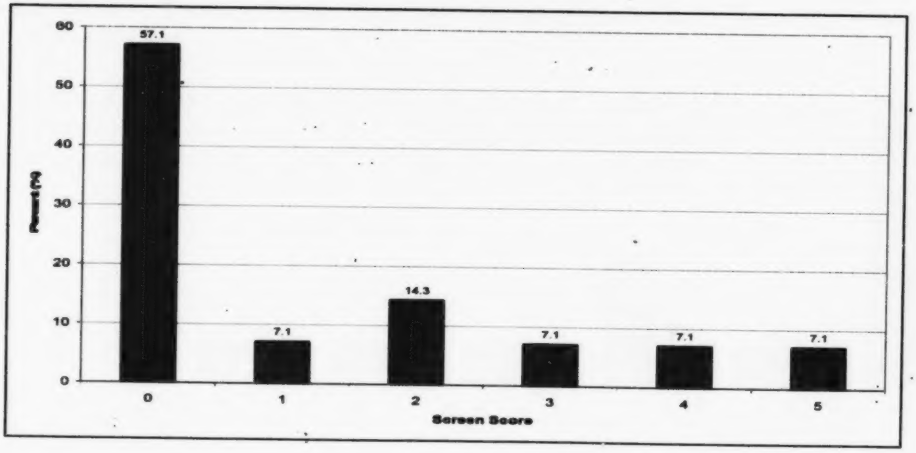


Figure A-8: Wild Rye Grass Reactivity, Children (N=14)

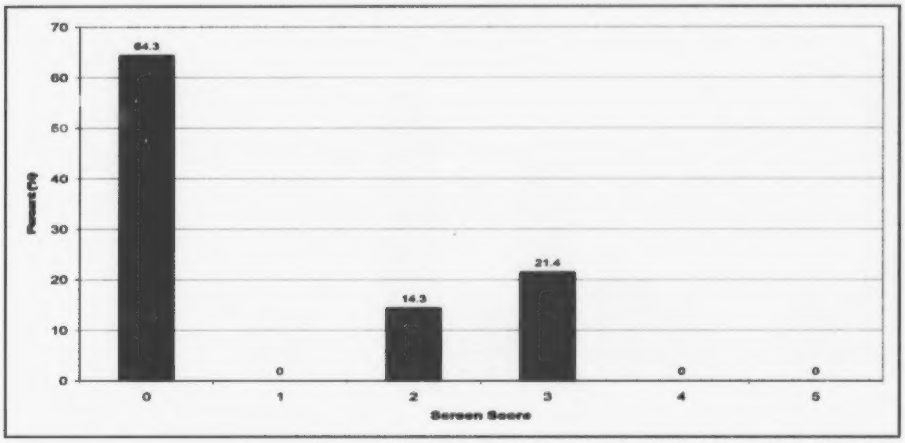


Figure A-9: Dandelion Pollen Reactivity, Children (N=14)

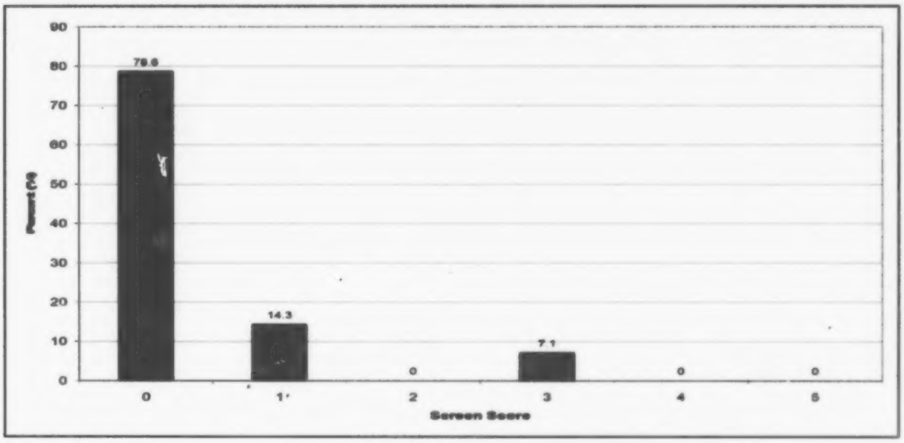
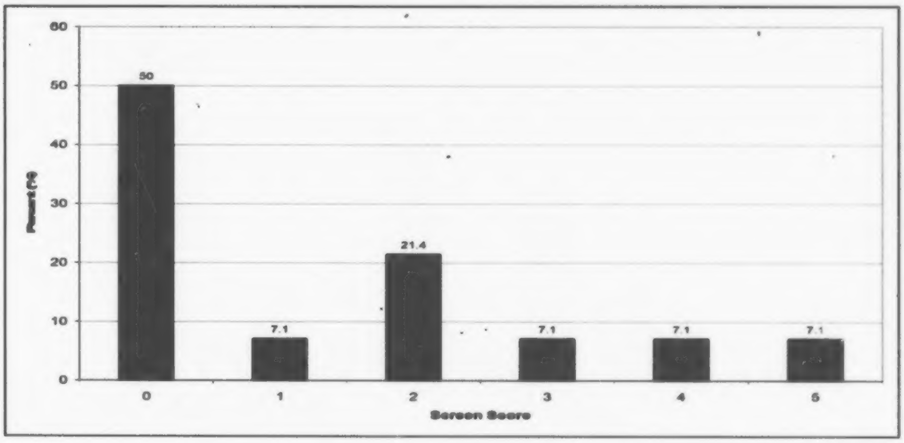


Figure A-10: Horse Dander Reactivity, Children (N=14)



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Appendix B

Supplementary - Immunoglobulin Gamma E

1.0 Materials and Methods

Study Population

The study population consisted of 207 adult and 52 child volunteers from Wabamun, Alberta. This population included a subset of 72 participants from the Paul Band reserve. There were three aspects to this study including providing serum samples, completing a questionnaire and participating in a lung function test. Not all participants completed every aspect of the study, for example, some participants may have provided serum samples, and not responded to a questionnaire, or complete a lung function assessment, etc. Children only provided serum samples. The total number of adult participants completing each element was:

- Serum samples: 165
- Questionnaire: 167
- Lung function testing: 183

Serum Samples

Serum samples were assayed for total and specific IgE at Dynacare Kasper Medical Laboratories, Edmonton, by Dr. Laurel Holth. The protocol for the IgE analysis was similar to the protocols used for the earlier studies. Some of the samples contained insufficient volume for repeated analysis; therefore, a hierarchy was set up as follows. In order of importance was the estimation of:

(1) Total IgE (kU/L).

(2) Inhalant allergen screen (Phadiotop test). This is a mixture of allergens that detects IgE antibodies to timothy grass, dandelion, silver birch, cat dander, dog epithelium, horse dander, rye and two molds, Alternaria tenuis and Cladosporium pteronnyssinus. A positive screen indicates that antibodies to one or more of the allergens were detected.

(3) Ingestant allergen screen. This is a food mix screen that detects allergens to one or more of the following: mild, egg white, wheat, soy, peanut and codfish.

(4) If inhalant screen positive, follow-up tests were done in the following order:
    (a) cat dander
    (b) dog dander
    (c) C. pteronnyssinus
    (d) Hollister Stier house dust mix
    (e) Timothy grass
    (f) A. tenuis mold
    (g) Birch pollen
    (h) Rye grass pollen
    (i) Dandelion pollen
    (j) Horse dander

(5) If food screen positive, follow-up tests were done in the following order:
   - (a) egg white
   - (b) milk
   - (c) peanut
   - (d) wheat
   - (e) cod fish
   - (f) soybean

Total IgE was quantitated using the Pharmacia CAP system® IgE TEMPO. The inhalant allergen screen was with Phadiotop® FEIA. The specific IgE used a RAST technology, which is semi-quantitative, and the positive results were scored on a scale of 0 – 5, 0 being negative, 5 being highly reactive. Data were provided in Excel spreadsheet to Dr. F. Green for analysis.

Questionnaire

The health questionnaire included questions on lifestyle, home and employment factors. Also included was the American Thoracic Society Questionnaire, which documents respiratory symptoms and illnesses.

Lung Function Measurement

To examine lung function, participants attempted at least three acceptable forced expiratory manoeuvres. Raw lung function measurements from spirometry were recorded and adjusted numbers (percent of predicted) were generated using Crapo prediction equations, which controls for gender, age and height. The largest FVC and FEV_1 were used for analysis; even if they did not come from the same curve.

2.0 Results

The following tables and figures are in addition to those provided in the WACEHEAP report.

Table C – 1: Comparison of Log IgE for selected characteristics,- Adults

Variable	Mean Log IgE	Statistical difference (p-value)
Gender		
Male	1.318	0.140
Female	1.148	
Paul Band Participant		
Yes	1.454	<0.001*
No	1.056	
Ever smoke cigarettes		
Yes	1.321	0.021*
No	1.073	
Currently Smoke		
Yes	1.398	0.005*
No	1.089	

Asthma, confirmed by doctor		
Yes	1.523	0.011*
No	1.144	
Pets in Household		
Yes	1.156	0.303
No	1.268	
Wheeze near trees		
Yes	1.636	0.012*
No	1.162	
Mother smoked during pregnancy		
Yes	1.297	0.290
No	1.127	
Birth Order		
Oldest	1.155	0.669
Middle	1.250	
Youngest	1.154	

*significant difference at $p<0.05$

Table C – 2: Comparison of mean FVC and FEV_1 percent of predicted for selected variables, Adults

Variable	Mean FVC (% predicted)	p-value	Mean FEV_1 (% predicted)	p-value
Inhalant screen				
Positive	97.09	0.886	94.56	0.448
Negative	97.53		97.20	
Ingestant screen				
Positive	98.30	0.886	97.10	0.952
Negative	97.41		96.67	
Asthma				
Yes	91.89	0.052	88.10	0.011*
No	98.87		98.24	
Paul Band Participant				
Yes	98.00	0.919	100.97	0.026*
No	98.25		95.15	

Born in Alberta				
Yes	99.04	0.219	99.06	0.030*
No	95.92		92.96	
Pets in household				
Yes	99.01	0.414	98.11	0.389
No	97.02		95.76	
Smoking in home				
Yes	96.37	0.376	95.70	0.546
No	98.66		97.44	
Ever smoke				
Yes	97.54	0.748	96.92	0.955
No	98.33		96.77	
Mother smoked during pregnancy				
Yes	96.71	0.485	92.37	0.110
No	99.28		98.69	
Birth order				
Oldest	96.87	0.757	95.29	0.283
Middle	98.88		99.41	
Youngest	98.24		95.47	

*significant difference at $p<0.05$

Table C – 3: Ingestant Screen Reactivity, Adults (N=6)

Score	Eggs n (%)	Milk n (%)	Peanut n (%)	Wheat n (%)	Codfish n (%)	Soya n (%)
0	4 (66.7)	4 (66.7)	3 (50.0)	4 (66.7)	6 (100.0)	4 (66.7)
1	1 (16.7)	0 (0.0)	0 (0.0)	1 (16.7)	0 (0.0)	0 (0.0)
2	1 (16.7)	2 (33.3)	1 (16.7)	0 (0.0)	0 (0.0)	1 (16.7)
3	0 (0.0)	0 (0.0)	2 (33.3)	1 (16.7)	0 (0.0)	1 (16.7)
4	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
5	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Note: Due to small cell counts, interpret with caution

Inhalant Screen Reactivity Results – Adults

Figure C – 1: Cat Dander Reactivity - Adults (N=34)

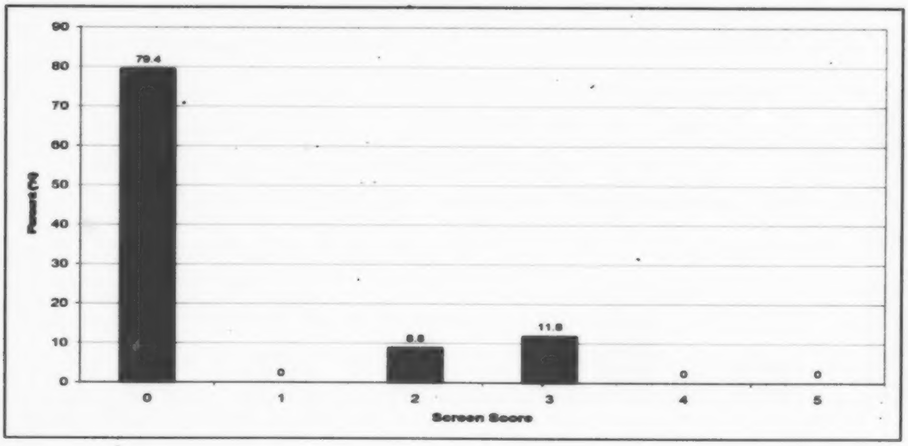


Figure C – 2: Dog Dander Reactivity - Adults (N=33)

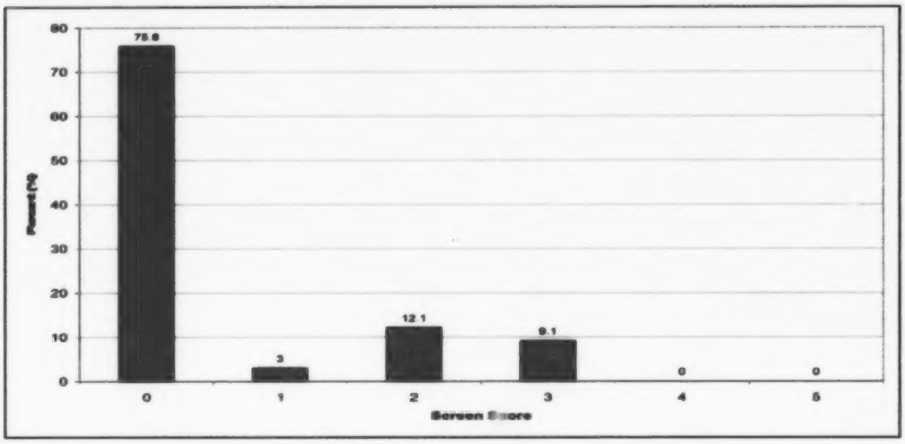


Figure C – 3: Dermataphagoides Pteronyssinus Reactivity - Adults (N=34)

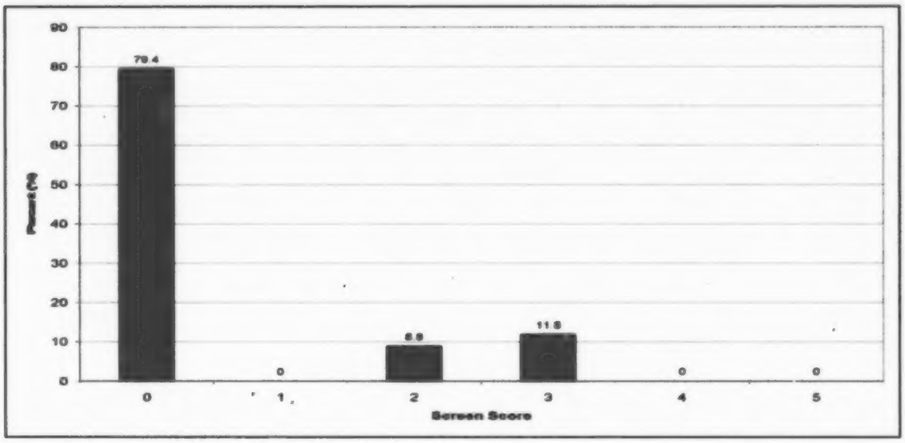


Figure C – 4: Hollister Stier Reactivity, Adults (N=32)

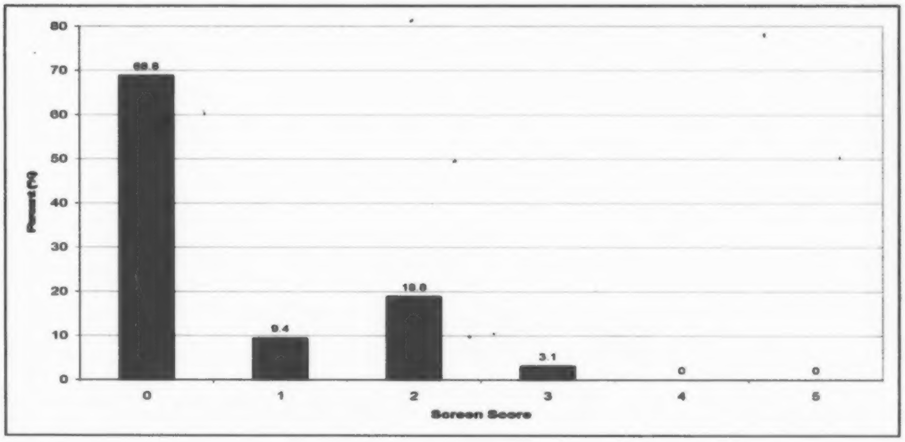


Figure C – 5: Timothy Grass Reactivity, Adults (N=33)

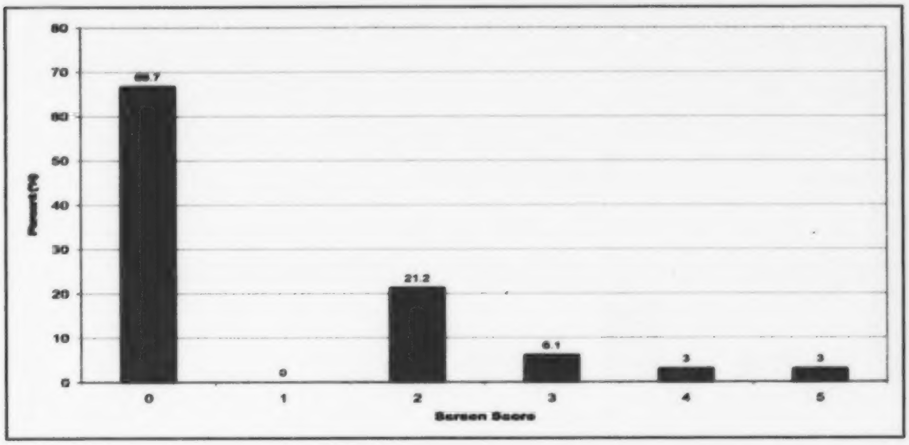


Figure C – 6: Alternaria Tenius Reactivity, Adults (N=33)

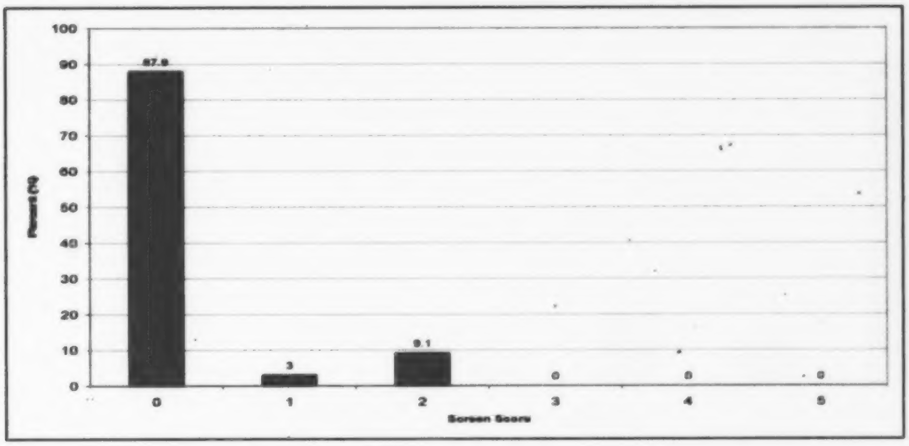


Figure C – 7: Birch Pollen Reactivity, Adults (N=33)

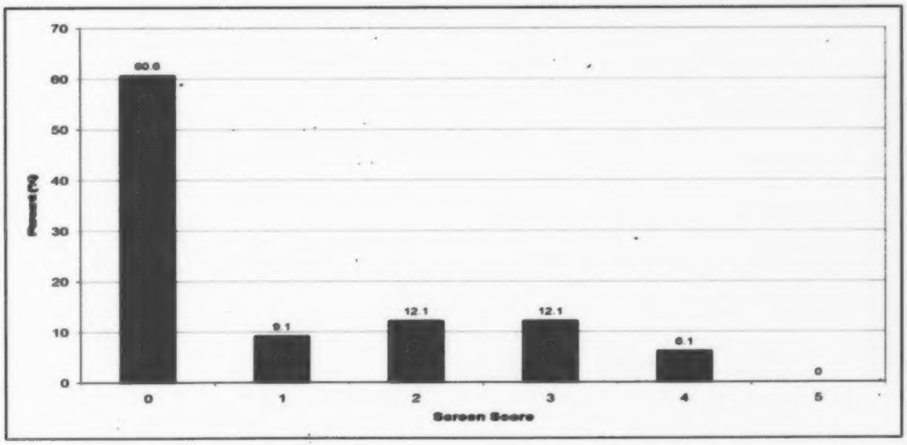


Figure C – 8: Wild Rye Grass Reactivity, Adults (N=32)

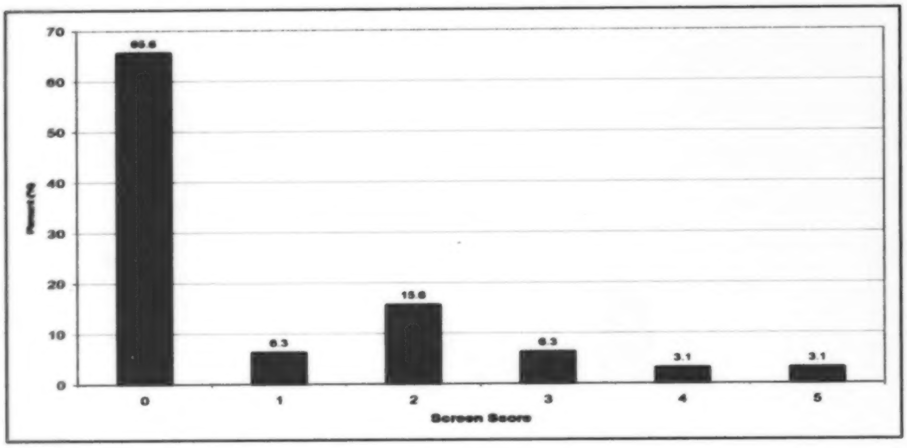


Figure C – 9: Dandelion Pollen Reactivity, Adults (N=32)

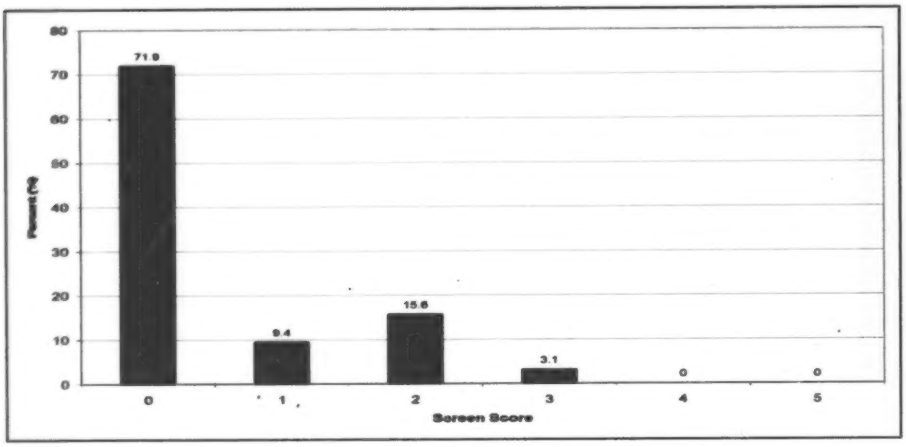
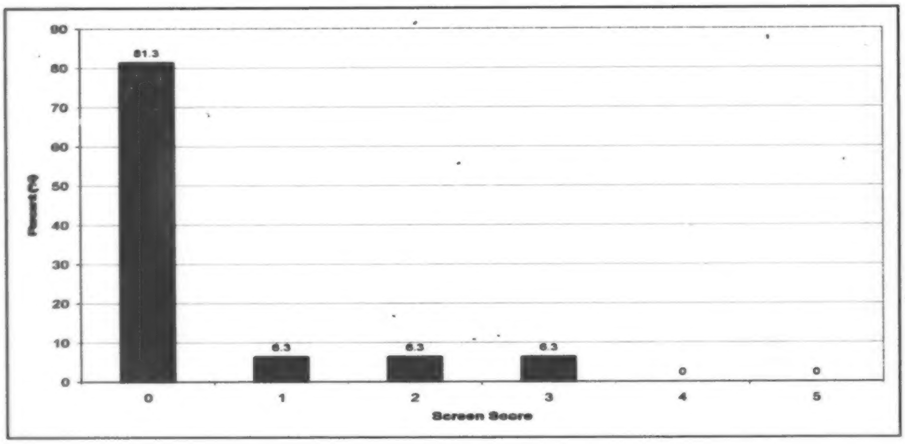


Figure C – 10: Horse Dander Reactivity, Adults (N=32)



Appendix C

Supplementary - Health Record Analysis

Asthma (ICD-9-CM = 493, ICD-10=J45-J46)

Asthma is a reversible airway obstruction that is characterized by hyperirritability and inflammation of the airways. Like previous reports (Health Surveillance, 2000), three case definitions of asthma were developed according to the nature of asthma and its statistical distribution in three settings of health care systems in Alberta.

Case Description of Asthma	Frequency of Visit over 10 Years	Health Care Settings
Probable Case – Stringent	>= 10 visits	Any single setting or combined
	>= 3 visits	All three settings (PV+ACCS+HV)
	>= 4 visits	Emergency room (ACCS)
	>= 5 visits	Any of two settings combined
Likely Case – Moderate	>=4 visits	Any single setting or combined
	>= 2 visits	Emergency room (ACCS)
	>=1 visit	Hospital (HV)
	>=3 visits	Any of two settings combined
Possible Case – Less Stringent	>=1 visit	PV or ACCS

Note: PV – fee-for-service physicians visit, ACCS – visit ambulatory care and classification system, HV – inpatient hospital visit.

Bronchitis (ICD-9-CM = 490-491; ICD-10=J40-J42)

Bronchitis is a respiratory tract exacerbation and obstruction due to narrowing of the airway lumen by infection, inflammation, mucosal thickening and mucus plugging. There are acute and chronic bronchitis; the latter involves in chronic cough and sputum production on most days for at least three consecutive months in two successive years (Toronto Notes, 2002). Like asthma, three case definitions of bronchitis were developed:

Case Description of Bronchitis	Frequency of Visit over 10 Years	Health Care Settings
Probable Case – Stringent	>= 6 visits	Any single setting or combined
	>= 3 visits	All three settings (PV+ACCS+HV)
	>= 3 visits	Emergency room (ACCS)
	>= 3 visits	Any of two settings combined
Likely Case – Moderate	>= 3 visits	Any single setting or combined
	>= 2 visits	Emergency room (ACCS)
	>=1 visit	Hospital (HV)
	>=2 visits	Any of two settings combined
Possible Case – Less Stringent	>=1 visit	PV or ACCS

Chronic Obstructive Pulmonary Disease (COPD: ICD-9-CM= 90-492,494,496; ICD-10=J40-J44, J47)

COPD is characterized by progressive obstruction to airflow and a history of inhalation of irritants. As in previous reports (Health Surveillance, 2000), three case definitions of COPD were developed:

Case Description of COPD	Frequency of Visit over 10 Years	Health Care Settings
Probable Case – Stringent	>= 7 visits	Any single setting or combined
	>= 3 visits	All three settings (PV+ACCS+HV)
	>= 3 visits	Emergency room (ACCS)
	>= 4 visits	Any of two settings combined
Likely Case – Moderate	>= 3 visits	Any single setting or combined
	>= 2 visits	Emergency room (ACCS)
	>=1 visit	Hospital (HV)
	>=2 visits	Any of two settings combined
Possible Case – Less Stringent	>=1 visit	PV or ACCS

Respiratory disorders (ICD-9-CM = 460-519; ICD-10 = J00-J99)

Respiratory disorders are the most common illness. The majority of respiratory disorders, particularly in children, are attributed to upper respiratory infections, such as common cold, sinusitis, tonsillitis, etc. Like our previous report (Health Surveillance, 2000), three case definitions of respiratory disorders were developed:

Case Description of Respiratory Disorders	Frequency of Visit over 10 Years	Health Care Settings
Probable Case – Stringent	>= 10 visits	Any single setting or combined
	>= 3 visits	All three settings (PV+ACCS+HV)
	>= 5 visits	Emergency room (ACCS)
	>= 6 visits	Any of two settings combined
Likely Case – Moderate	>= 5 visits	Any single setting or combined
	>= 3 visits	Emergency room (ACCS)
	>= 1 visit	Hospital (HV)
	>= 4 visits	Any of two settings combined
Possible Case – Less Stringent	>=1 visit	PV or ACCS

Appendix D

Prevalence of Multiple Sclerosis In Wabamun, Alberta

Background

Multiple Sclerosis (MS) is a debilitating disease of unknown etiology, but is thought to be an autoimmune disease with a long latency period.[1,2] Various possible risk factors for developing MS have been proposed, among them infectious diseases in childhood,[3] genetic factors,[4] gene-environment interactions,[5] exposure to heavy metals,[6,7] and lifestyle factors such as diet[1] and smoking.[8] Individuals may present with a wide range of symptoms including changes in sensation, visual problems, mood disorders and difficulties with coordination and movement.

Prevalence of MS differs by sex[1] and geography.[9,10] Anecdotal reports of an apparent excess of cases within small geographic areas or "clusters," have led to in-depth analyses of prevalence rates of MS in several parts of Alberta.[11] This analysis addresses similar community questions and uses a similar methodology to examine the prevalence of MS in the Wabamun area.

The objective of this analysis was to examine the prevalence of MS in the Wabamun area of Alberta. This analysis also allows us to determine any difference between the rate of MS in Wabamun and the provincial average.

Methods

For this analysis a Wabamun resident was defined as having lived in Wabamun for at least one year between 1995 and 2004 (inclusive). The Wabamun area falls largely (81%) within one postal code area: T0E 2K0.

Administrative data sources are becoming increasingly important for surveillance and research.[12] Alberta Health and Wellness maintains physician billing information for the province. Each patient encounter with physicians who use fee-for-service billing practice is coded according to the International Classification of Diseases, 9th Revision Clinical Modification (ICD-9-CM). For this analysis, physician visits between 1995 and 2004 were extracted if the individual had two or more services for multiple sclerosis (ICD-9-CM code 340) or one or more visits with a neurologist over the 10 year period. This definition limits the number of false positives identified. A false positive is those who are identified as having MS but don't actually have the disease. The use of these parameters on the definition may provide a more accurate estimate of MS rates.

The cases were extracted from the data and standardized rates were calculated using indirect methods. This method takes the estimated prevalence of multiple sclerosis for the entire province and then estimates the number of expected cases in the Wabamun area using the Wabamun area population structure for the time period in question. The standardized morbidity ratio (SMR) uses the indirect method of adjustment in order to compare the morbidity or mortality of a given disease (i.e. MS) in a given area with a standard (in this case the entire province of Alberta). The ratio of observed cases to the expected cases was calculated for each time period, as were 95% confidence intervals.

For this analysis, the 10 year period was divided into two time blocks: 1995-1999 and 2000-2004, to provide more sensitive estimates.

Results

Wabamun

Five men and three women who had lived in Wabamun for at least one year between 1995 to 2004 were defined as having MS in this analysis. They ranged in age from 25 to 68. The women averaged less than 3 MS related visits to a physician per person, while the men averaged seven visits per person over the 10 year time period of the study. Of these eight people, five people (63 per cent) had visited a neurologist at least once between 1995 and 2004.

The observed and expected numbers of cases per year are calculated for five year time periods. The yearly numbers of cases summed over a five year period gives the observed cases. The expected number of cases for the Wabamun area was calculated from the provincial rate and the population structure of the Wabamun area.

The observed and expected number of multiple sclerosis cases for each five year period, along with the standardized mortality ratio, 95 percent confidence intervals and p-values are shown in Table One.

Table One: Standardized Mortality Rates for MS in Wabamun in five year intervals 1995-2004

Five year period	Observed Cases of MS	Expected Cases of MS	Standardized mortality ratio (observed/expected)	95% Confidence interval	P value
1995-1999	19	23.8	0.80	0.49 – 1.22	0.33
2000-2004	28	32.4	0.86	0.59 – 1.23	0.44

Discussion

Given the age distribution of the Wabamun area and using the population structure of Alberta as the standard, the number of expected cases of MS for the Wabamun area was within the ranges of what is expected, and were not significantly different from provincial rates in any age group.

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